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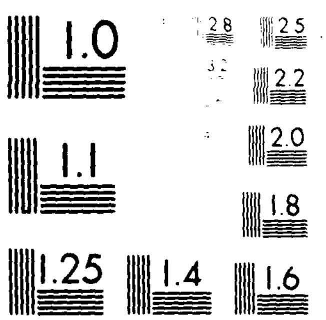

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MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

VERIFICATION STUDY
MULESHOE VALLEY, NEVADA
VOLUME I - SYNTHESIS

PREPARED FOR
BALLISTIC MISSILE OFFICE (BMO)
NORTON AIR FORCE BASE, CALIFORNIA

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents results of geotechnical studies which were completed in Muleshoe Valley, Nevada. Included are base data consisting of depth to rock, depth to ground water, seismic refraction surveys, electrical resistivity surveys, sieve analyses and soil profiles.

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MX SITING INVESTIGATION
GEOTECHNICAL EVALUATION

VERIFICATION STUDY - MULESHOE VALLEY
NEVADA

VOLUME I - SYNTHESIS

Prepared for:

U.S. Department of the Air Force
Ballistic Missile Office (BMO)
Norton Air Force Base, California 92409

Prepared by:

Ertec Western, Inc.
3777 Long Beach Boulevard
Long Beach, California 90807

30 June 1981

FOREWORD

This report was prepared for the U.S. Department of the Air Force, Ballistic Missile Office (BMO), in compliance with Contract No. F04704-80-C-0006, CDRL Item 004A6. It contains an evaluation of the suitability of Muleshoe Valley, Nevada, for siting the MX Land Mobile Advanced ICBM system and presents the geological, geophysical, and soils engineering data upon which the evaluation is based. It is one of a series of reports covering the results of Verification studies in the Nevada-Utah region.

Verification studies, which were started in 1979, are the final phase of a site-selection process which was begun in 1977. The Verification objectives are to define sufficient area suitable for deployment of the MX system and to provide preliminary soils engineering data. Previous phases of the site-selection process were Screening, Characterization, and Ranking. In preparing this report, it has been assumed that the reader will be familiar with the previous studies.

Volume I of this report is a synthesis of the data obtained during the study. It contains discussions relative to the horizontal and vertical shelter basing modes. Volume II is a compilation of the data which may be used for independent interpretations or analyses.

VOLUME I

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LIST OF TABLES (Cont.)

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LIST OF DRAWINGS

TABLE OF CONTENTS (Cont.)

LIST OF DRAWINGS (Cont.)

3.0 GEOTECHNICAL SUMMARY

1.0 INTRODUCTION

1.1 PURPOSE AND BACKGROUND

This report presents the results of the geotechnical studies which were completed in Muleshoe Valley, Nevada, during the fall of 1979 and summer of 1980. The work was done as part of Ertec Western, Inc's. (formerly Fugro National, Inc.) Verification studies which have two major objectives:

1. Verify and refine boundaries of areas which are geotechnically suitable for the two proposed basing modes (horizontal and vertical shelter) for the MX missile system; and
2. Provide preliminary physical and engineering characteristics of the soils.

This report contains two volumes. This volume is a synthesis of the data collected during the studies. The data obtained as a result of the field and laboratory work are compiled by activity in Volume II.

The Verification Program is the final phase of a site-selection process which started in 1977. The objective of the site-selection process is to identify and rank geotechnically suitable areas which are sufficiently large for deployment of the Missile-X (MX), an advanced intercontinental ballistic missile system. The phases involved are Screening, Characterization, Ranking, and Verification. Screening used existing information from literature to identify areas which appeared to be suitable for deployment of MX based on geotechnical, cultural, and environmental criteria. Potentially usable regions were identified in seven western states. Both Characterization and

Verification programs use field studies as well as published information. Following Screening and Characterization, the available geotechnical data were used to rank the seven regions. The ranking, based on relative construction costs, was made for various basing modes. Characterization studies emphasized collection of information to characterize geologic units with respect to construction of the MX basing options. Verification studies also obtain information on construction properties of the geologic units, but special emphasis is given to refining the usable area boundaries that were drawn during the Screening studies. Table 1-1 summarizes the investigative techniques being employed during Verification studies.

Figure 1-1 shows the site selection schedule and identifies the FNI technical report for each element in the process. Based on the results of Screening, Characterization, and Ranking, contiguous portions of Nevada and Utah were selected as a candidate siting region for the MX system, and Verification studies were started in 1978. As shown in Figure 1-1, the Verification Program is continuing, and field work should be completed in 1981. The valleys for which reports have been issued on the Verification studies are shown in Figure 1-2. The presently defined geotechnically suitable areas for the Nevada-Utah siting region are shown in Drawing 1-1. These areas will be adjusted as Verification studies are completed.

1.2 SCOPE OF STUDY

The field work in Muleshoe Valley was done in October and November, 1979 and August 1980. Table 1-2 lists the types and

OBJECTIVES → **VERIFICATION OF SUITABLE AREA F**

DATA FOR EVALUATIONS → TERRAIN PARAMETERS | GEOLOGIC HAZARD | DE

FIELD TECHNIQUES AND APPLICATIONS →

TERRAIN PARAMETERS

Geologic mapping

- Identification and limits of areas with slopes greater than 5% and 10% grade

GEOLOGIC HAZARD

Geologic mapping

- Identification of faults and lineaments

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- Depth from geolog
- Geomo erosion

Seism

- Subsur rock li
- Deline layers velocit
- Occurr
- Publi

OF SUITABLE AREA FOR MX DEPLOYMENT

HAZARD

mapping

- of faults and

50'/150' DEPTH TO ROCK

Geologic mapping

- Surface limits of rock
- Depth to rock from topographic and geologic interpretation
- Geomorphic expression and erosion history

Seismic refraction surveys

- Subsurface projection of rock limits
- Delineation of high velocity layers from p - wave velocities (> 7000 fps)

Borings

- Occurrence of rock

Existing data

- Published literature

50'/150' DEPTH TO GROUND WATER

Geologic mapping

- Obtain water depths from wells in study area
- Monitoring wells
- Occurrence of ground water

Electrical resistivity/ seismic refraction surveys

- Provide supplemental data to support presence or absence of ground water

Existing data

- Published literature

EXTENT AND CHARACTERISTICS OF SOILS

Geologic mapping

- Extent of surficial soil units
- Surficial soil types

Borings

- Identification of subsurface soil types
- In situ soil density and consistency
- Samples for laboratory testing

Trenches and test pits

- Identification of surface and subsurface soil types
- Degree of induration and cementation of soils
- In situ moisture and density of soil
- Samples for laboratory testing

Cone penetrometer tests

- In situ soil strength

Laboratory tests

- Physical properties
- Engineering properties – shear strength, compressibility
- Chemical properties

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- Comp
- Layer

E

- Electi
- Layer

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CHARACTERISTICS OF BASIN FILL

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GEOPHYSICAL PROPERTIES

Seismic refraction surveys

- Compressional wave velocities
- Layering of soil

Electrical resistivity surveys

- Electrical conductivity of soils
- Layering of soil

ROAD DESIGN DATA

Trenches and test pits

- Identification of soil types
- In situ soil density and moisture

Cone penetrometer tests

- In situ soil strength
- Thickness of low strength surficial soil

Laboratory tests

- Physical properties
- Compaction and CBR data
- Suitability of soils for use as road subgrade, subbase or base

Existing data

- Suitability of soils for use as road subgrade, subbase, or base
- Behavior of compacted soils

EXCAVATABILITY AND STABILITY

Borings

- Subsurface soil types
- Presence of cobbles and boulders
- In situ density of subsurface soils
- Stability of vertical walls

Trenches and test pits

- Subsurface soil types
- Subsurface soil density and cementation
- Stability of vertical walls
- Presence of cobbles and boulders

Laboratory tests

- Physical properties
- Engineering properties

Geologic mapping

- Distribution of geologic units

Seismic refraction surveys

- Excavatability

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PRELIMINARY GEOTECHNICAL CONSIDERATIONS AND RECOMMENDATIONS

XCAVATABILITY AND STABILITY

Borings

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FIELD TECHNIQUES VERIFICATION STUDIES

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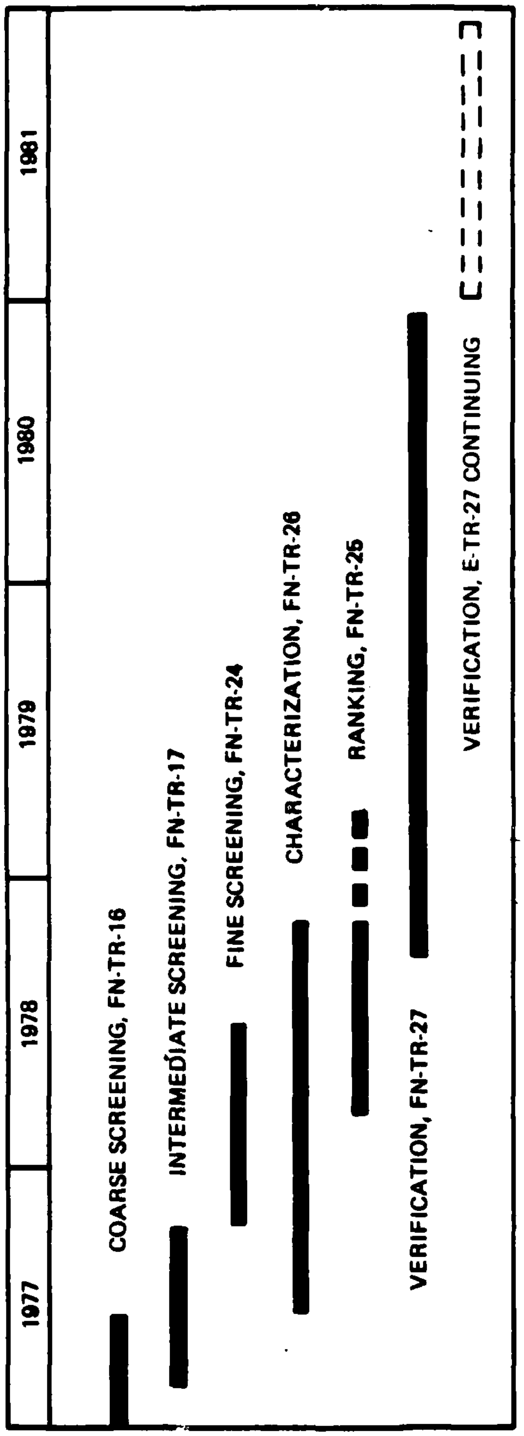
TABLE 1-1



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SUMMARY OF SITE
SELECTION SCHEDULE

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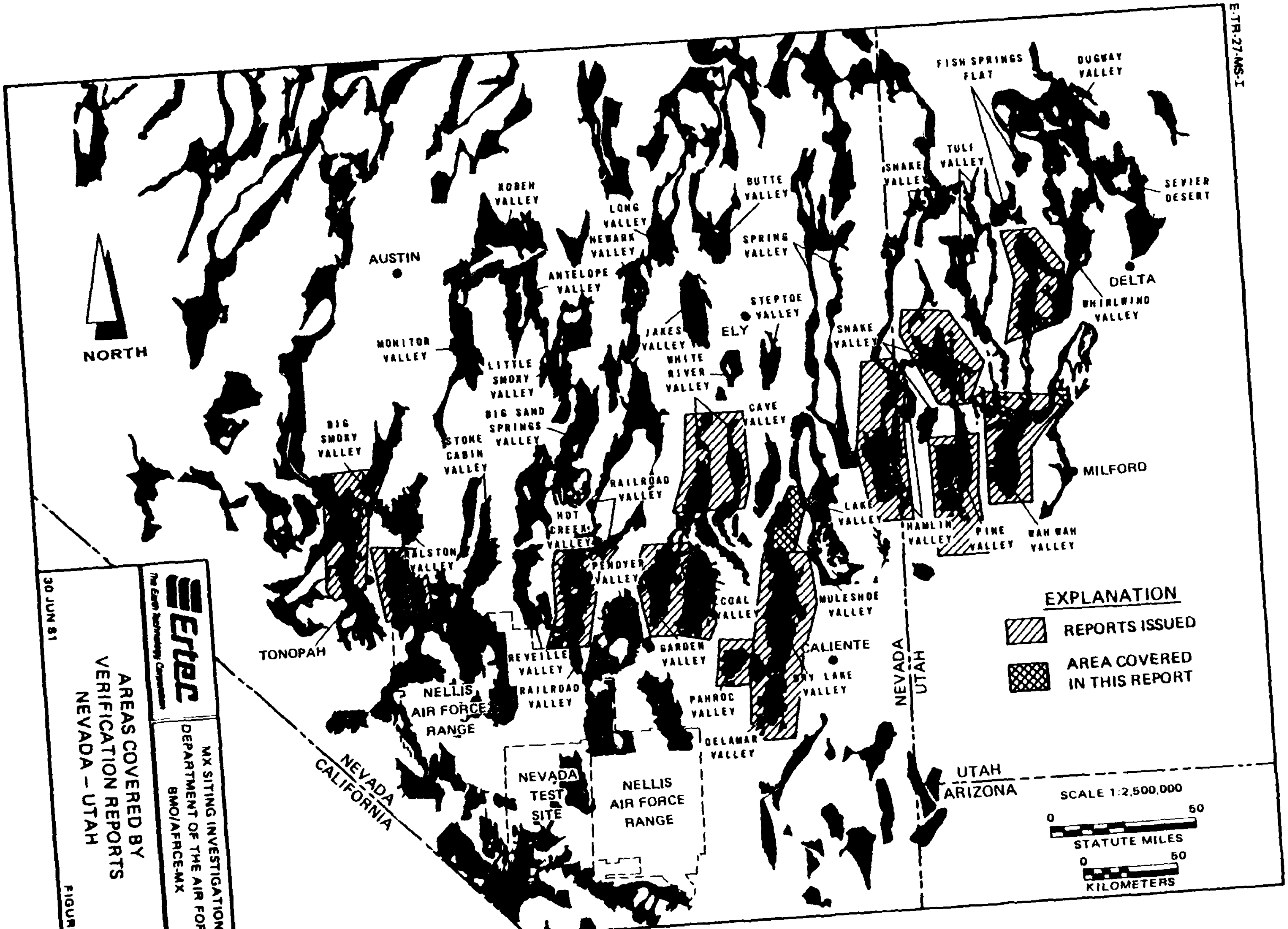
FIGURE 1-1



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AREAS COVERED BY
VERIFICATION REPORTS
NEVADA – UTAH

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FIGURE 1-2

GEOLOGY AND GEOPHYSICS — FIELD ACTIVITIES

TYPE OF ACTIVITY	NUMBER OF ACTIVITIES
Geologic mapping stations	48
Shallow refraction	10
Electrical Resistivity	9

ENGINEERING—FIELD ACTIVITIES

ACTIVITY	NO.	NOMINAL DEPTH - FEET (METERS)
Borings	3	100 (30)
Trenches	4	14 (4)
	4	3 - 6 (1 - 2)
Test pits	5	5 (2)
	4	2 - 4 (1)
Surficial soil samples	7	1 - 2 (1)
	1	4 (1)
CPT Soundings	24	1 - 43 (0.3 - 13)

ENGINEERING—LABORATORY TESTS

TYPE OF TEST	NUMBER OF TESTS
Moisture/density	52
Specific gravity	4
Sieve analysis	49
Hydrometer	2
Atterberg limits	27
Consolidation	1
Unconfined compression	2
Triaxial compression	2
Direct shear	2
Compaction	4
CBR	4
Chemical analysis	5

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SCOPE OF ACTIVITIES
MULESHOE VALLEY, NEVADA

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TABLE 1-2

number of field activities that were performed in Muleshoe Valley. The techniques of investigation are discussed in the appendix.

Access to public land in Muleshoe Valley was arranged through the Ely, Nevada, district office of the Bureau of Land Management (BLM). At BLM's request, all field activities were performed along existing roads or trails to minimize site disturbance. The restriction has limited the studies that could be performed in some areas. Archaeological and environmental surveys were performed at each proposed activity location. Activity locations were changed in those few places where a potential environmental or archaeological disturbance was identified.

1.3 DISCUSSION OF ANALYSIS TECHNIQUES

1.3.1 Determination of Suitable Area

The number of field activities performed during this investigation established a relatively small data base for characterizing such a large area, especially in view of its complex geology and frequent soil variations. In some cases, the environmental restrictions limited the ability to achieve an optimum distribution of data points. Nevertheless, care has been taken to optimize the information that could be obtained within specified cost and time constraints of the project. The determination of geotechnically suitable area is based on the exclusion criteria given in Appendix Table A2-1. The main attention was focused on the study of depth to rock, depth to water, terrain conditions,

and near-surface soil characteristics. Maps showing the results of these studies are included in Section 3.0 and the composite map of area suitable for deployment is included in Section 2.0.

a. Depth to rock: For a Verification study, the depth to rock is estimated, and areas where the depths to rock are less than 50 and 150 feet (15 and 46 m) are outlined by contours (Drawing 3-3). These contours are interpreted from published well data, geologic literature, boring logs, geophysical data, and field observations. The interpretation considers the presence or absence of range-bounding faults, bedding plane attitudes, topographic slopes, evidence of erosional features such as pediments, and the presence or absence of young volcanic rocks.

b. Depth to water: Only one ground-water data point is available for Muleshoe Valley and is recorded by the State of Nevada Engineer's Office (Table II-3-1, Volume II). This data point suggests that water in Muleshoe Valley is probably deeper than 150 feet (46 m). However, the overall data are an insufficient basis for conclusions and, therefore, no contours are shown in Drawing 3-4.

c. Terrain: The map of terrain conditions (Drawing 3-5) was compiled to show areas unsuitable for either vertical or horizontal shelters due to either high surface slopes or frequent deep drainage incisions (criteria are described on Appendix Table A2-1). The interpretation of terrain exclusions is based on a combination of field- and office-derived data. Field data include the visual information obtained by reconnaissance of the

areas and measurements of typical drainage incision depths. Reconnaissance frequently results in recognition of areas with locally steep slopes (for example, the sides of large and deeply incised drainages) that are not recognizable from data available in the office. Office-determined data consists of: 1) interpretation of 1:60,000-scale black and white and 1:25,000-scale color aerial photographs to determine terrain exclusions in areas lacking road access; and 2) topographic map analysis to define areas of greater than 10 percent slope.

d. Faults: The faults shown on the geologic map (Drawing 3-2) are mapped primarily from high resolution photogeologic studies and field reconnaissance. These faults are primarily Quaternary age but some late Tertiary faults may also be included. Generally, those within alluvial deposits are of Quaternary age. The faults shown within mountain blocks or at the mountain-valley contact are of unknown age but are most likely of late Tertiary and/or Quaternary age and probably have been active under the present tectonic regime. Since they are not within the siting areas, they have not been studied. Published maps also show numerous inferred faults buried under the alluvium along the mountain-valley contacts. These faults are commonly verified by geophysical studies. They may represent earthquake hazards, but since they have no surface expression, they cannot be verified by the reconnaissance methods used in the fault studies.

1.3.2 Determination of Basin-Fill Characteristics

In addition to the primary objective of refining the boundaries of the suitable area, a secondary objective was to provide preliminary physical and engineering properties of the basin-fill materials. These data will be used for preliminary engineering design studies, will assist in planning future site-specific studies, and will be used by other MX participants.

The geologic map (Drawing 3-2) showing the distribution of surficial soils is based on the interpretation of aerial photos, field mapping, and information from trenches, test pits, and surficial soil samples.

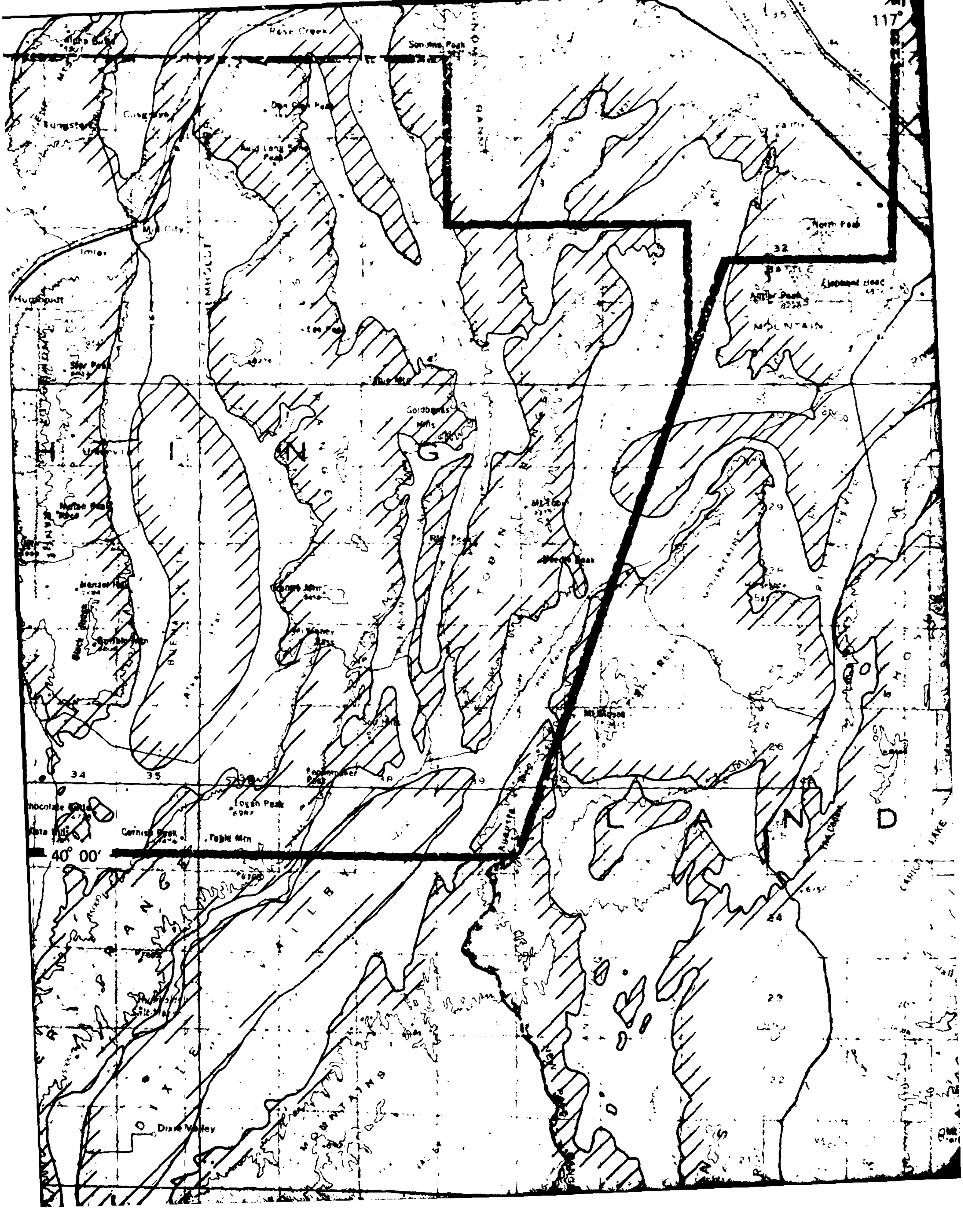
The investigations of engineering properties were designed primarily to obtain information needed for construction activities. For Verification studies, surficial soil conditions, as related to road construction, a major cost item, received particular emphasis. Emphasis was placed also on soil conditions in the upper 20 feet (6 m) to provide information to the approximate depth of excavation for the horizontal shelter basing mode.

Data obtained from borings, trenches, test pits, seismic refraction lines, and laboratory tests were used to estimate soil properties to a depth of 20 feet (6 m). The data are limited since field activities included only three borings, eight trenches, nine test pits, and 10 seismic refraction lines. There may be soil conditions in the upper 20 feet (6 m) that were not encountered by these 30 data points. The number of

data points available for description of the surficial soils was increased to 62 by using eight surface samples and 24 Cone Penetrometer Test (CPT) soundings to measure in-situ properties.

The soil parameters between a depth of 20 and 100 feet (6 and 30 m) are based on data obtained from only three borings and 10 seismic refraction lines. The spacing between borings ranged from 3.5 to 9 miles (6 to 14 km), therefore, the data presented may not be representative of the entire valley.

The length of the seismic refraction lines was chosen to investigate the velocity profile to a depth of at least 150 feet (46 m), which is the depth of interest for the vertical shelter basing mode.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Son-ma Peak
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Auld Lang Syne Peak
Mill City
Imlay
Humboldt
Lee Peak
Star Peak
Tobin Mtn
Goldbanks Hills
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North Peak
BATTLE
Antler Peak
MOUNTAIN
Needle Peak
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Logan Peak
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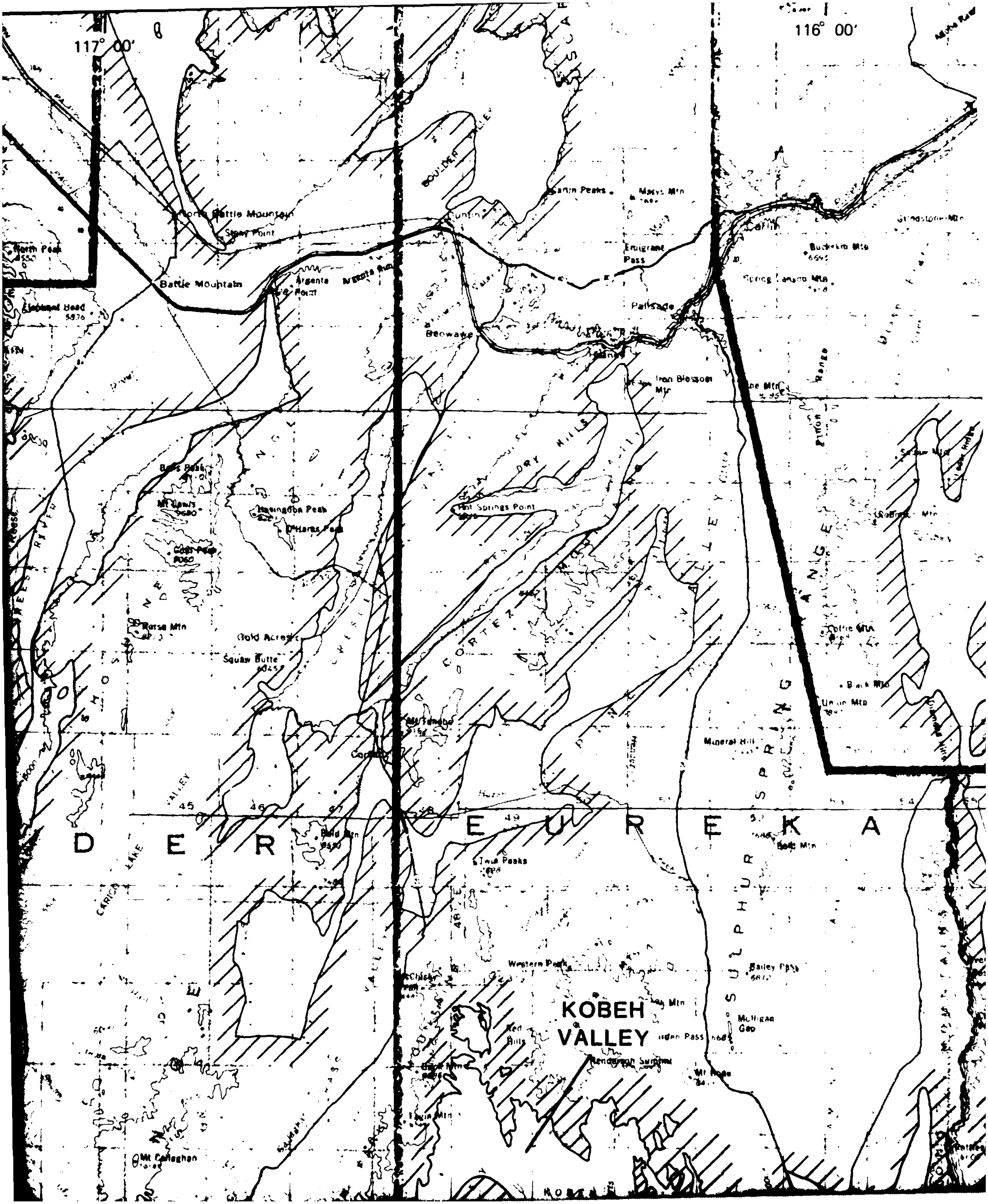

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Stony Point
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Elephant Head
Argenta
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BOULDER VALLEY
Carlin Peaks
Emigrant Pass
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Buckskin Mtn
Palisade
Beowawe
Iron Blossom Mtn
DRY HILLS
Hot Springs Point
Mt Lewis
Cortez
Gold Acres
Squaw Butte
Horse Mtn
Mt Tenabo
Mineral Hill
Coffee Mtn
Black Mtn
Union Mtn
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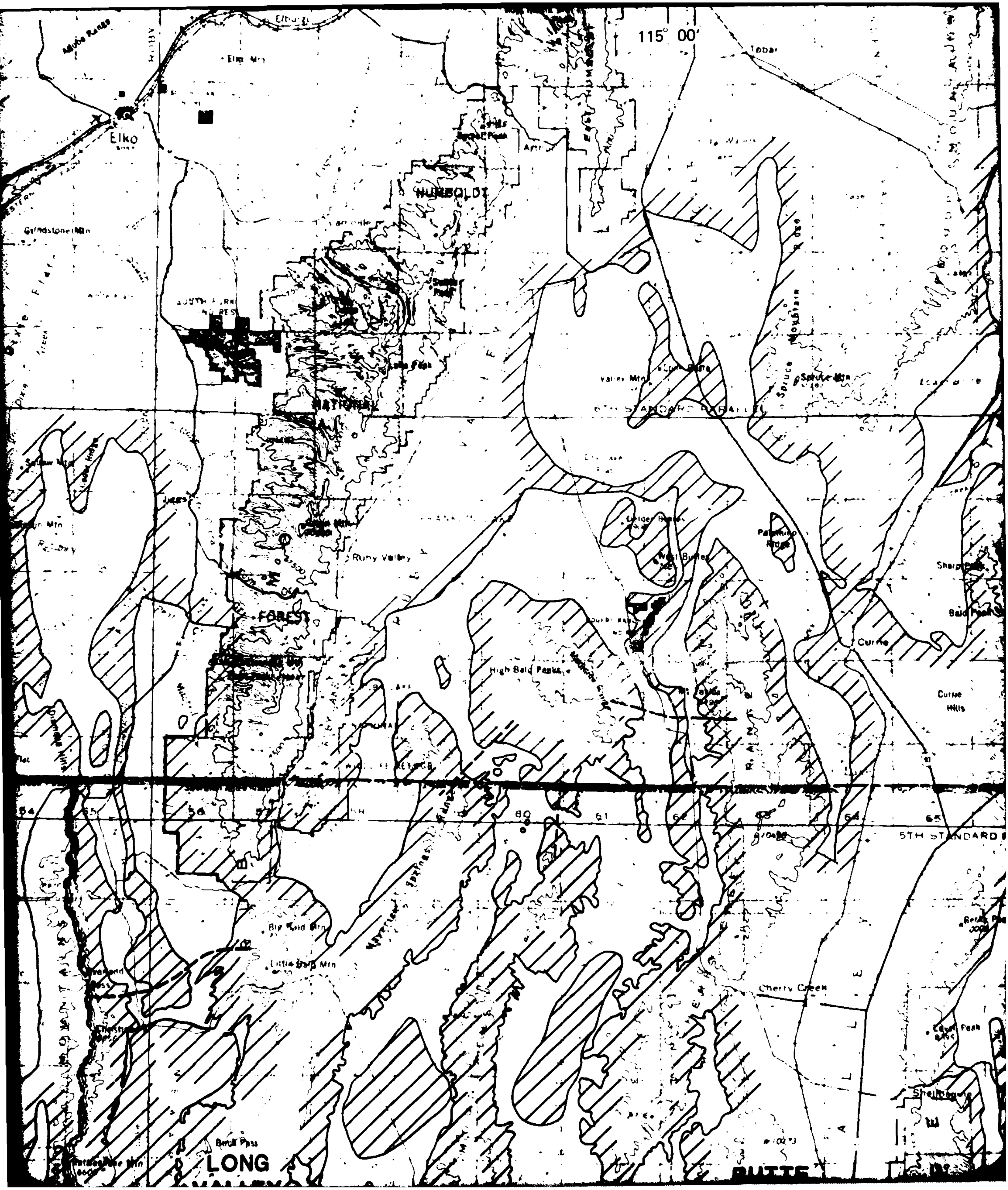
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West Buttes
Palomino Ridge
Sharp Peak
Bald Peak
Currie
Currie Hills
High Bald Peak
5TH STANDARD
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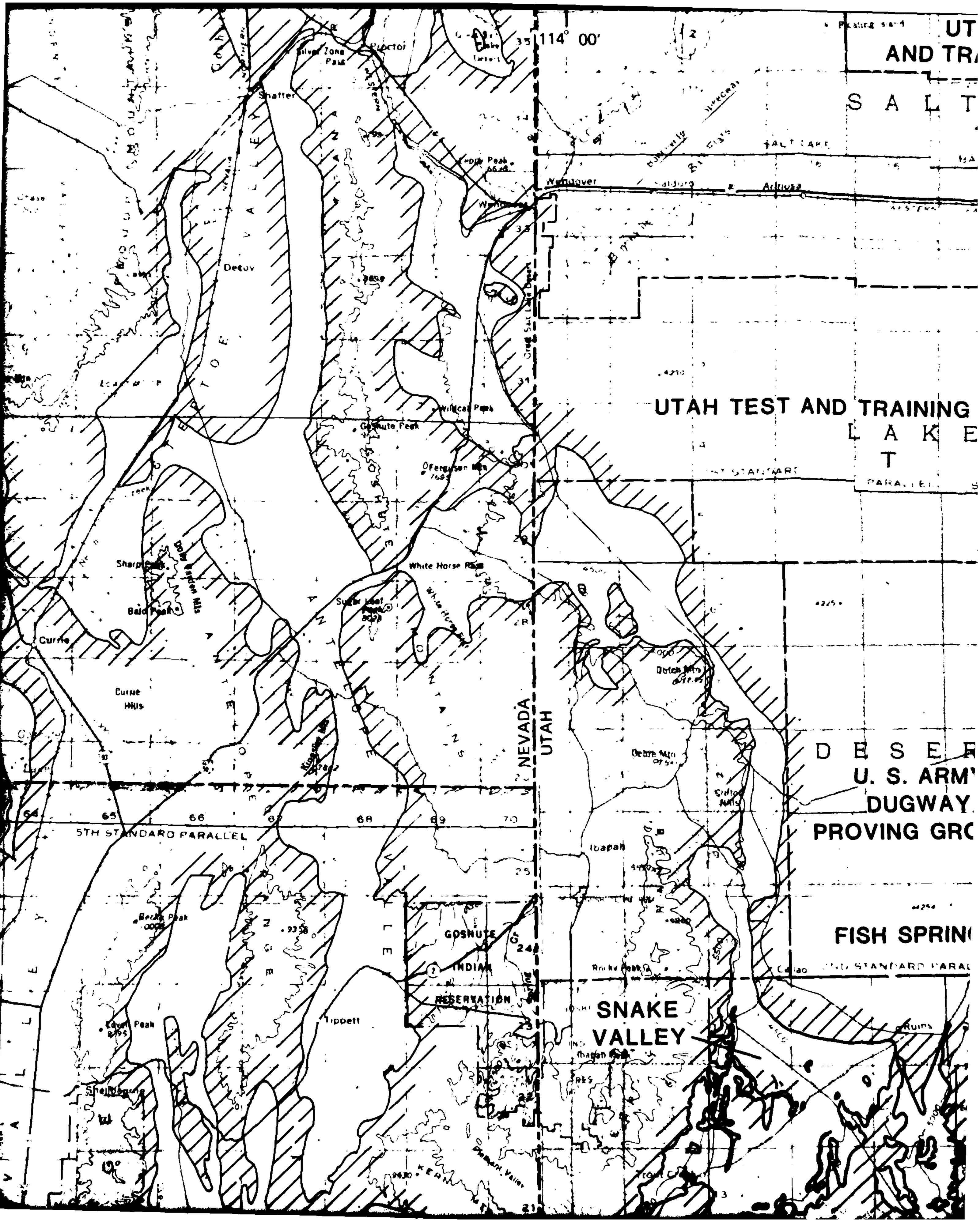

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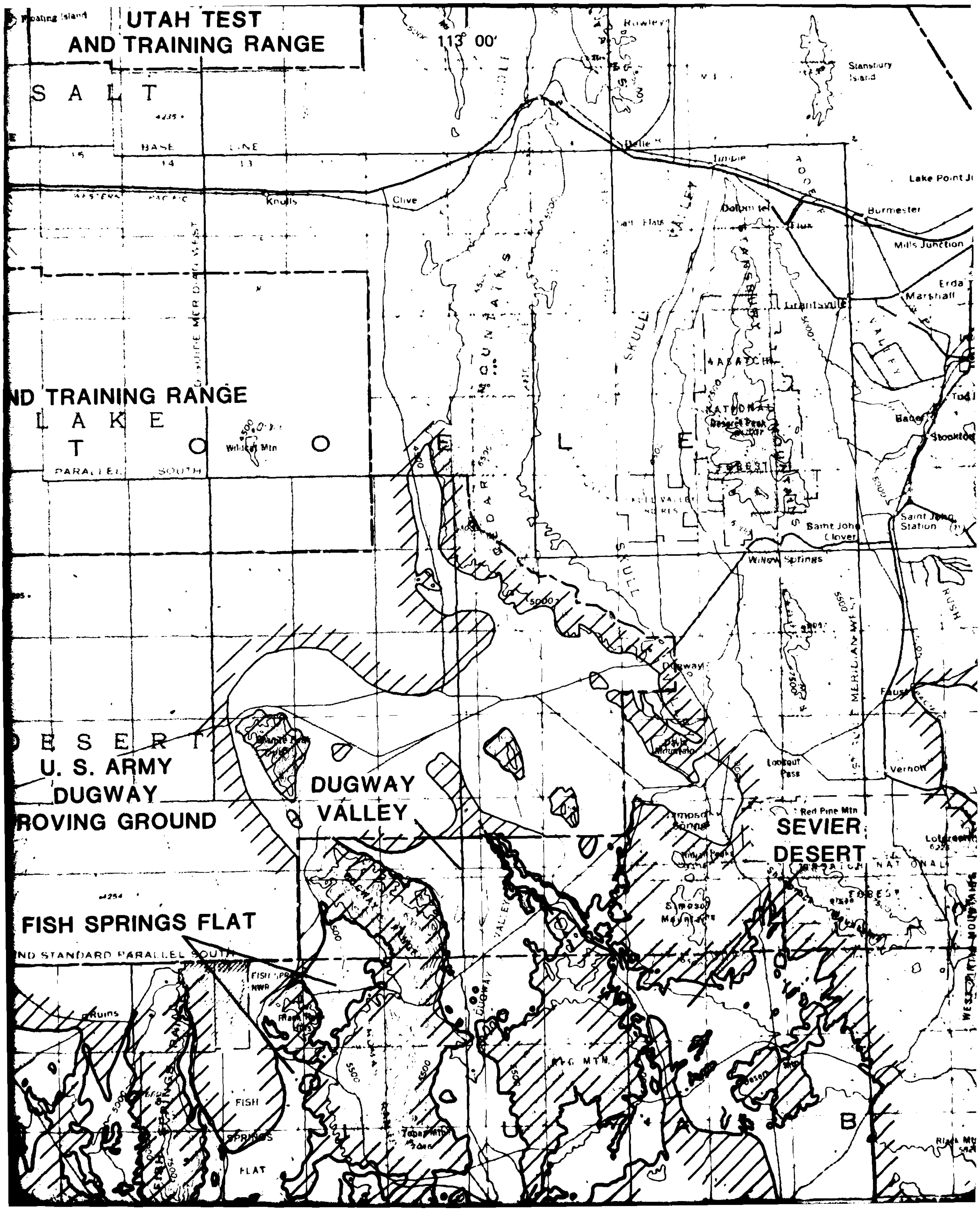
Wildcat Peak
Ferguson Mtn
White Horse Pass
Sugar Loaf Peak
Sharp Peak
Bald Peak
Currie
Currie Hills
Dutch Mtn
NEVADA
UTAH
DESERT
U. S. ARMY
DUGWAY
PROVING GRO
5TH STANDARD PARALLEL
Ibapah
GOSHUTE
INDIAN
RESERVATION
FISH SPRING
Callao
Tippett
Berry Peak
SNAKE
VALLEY
Ibapah Peak
Ruins
Pleasant Valley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Stansbury Island
Rowley
Knolls
Clive
Timpie
Burmester
Lake Point Jc
Mills Junction
Erda
Marshall
Grantsville
Dolomite
Flux
Salt Flats
Wildcat Mtn
Deseret Peak
Saint John
Clover
Saint John Station
Willow Springs
Dugway
Faust
Vernon
Lookout Pass
Red Pine Mtn
Simpson Springs
Simpson Mountains
Davis Mountain
Granite Peak
FISH SPRINGS NWR
Ruins
FISH
SPRINGS
FLAT
Topaz Mtn
Black Mtn
BASE LINE
WESTERN PACIFIC
SALT LAKE MERIDIAN WEST
PARALLEL SOUTH
SKULL VALLEY
CEDAR MOUNTAINS
RUSH
DUGWAY

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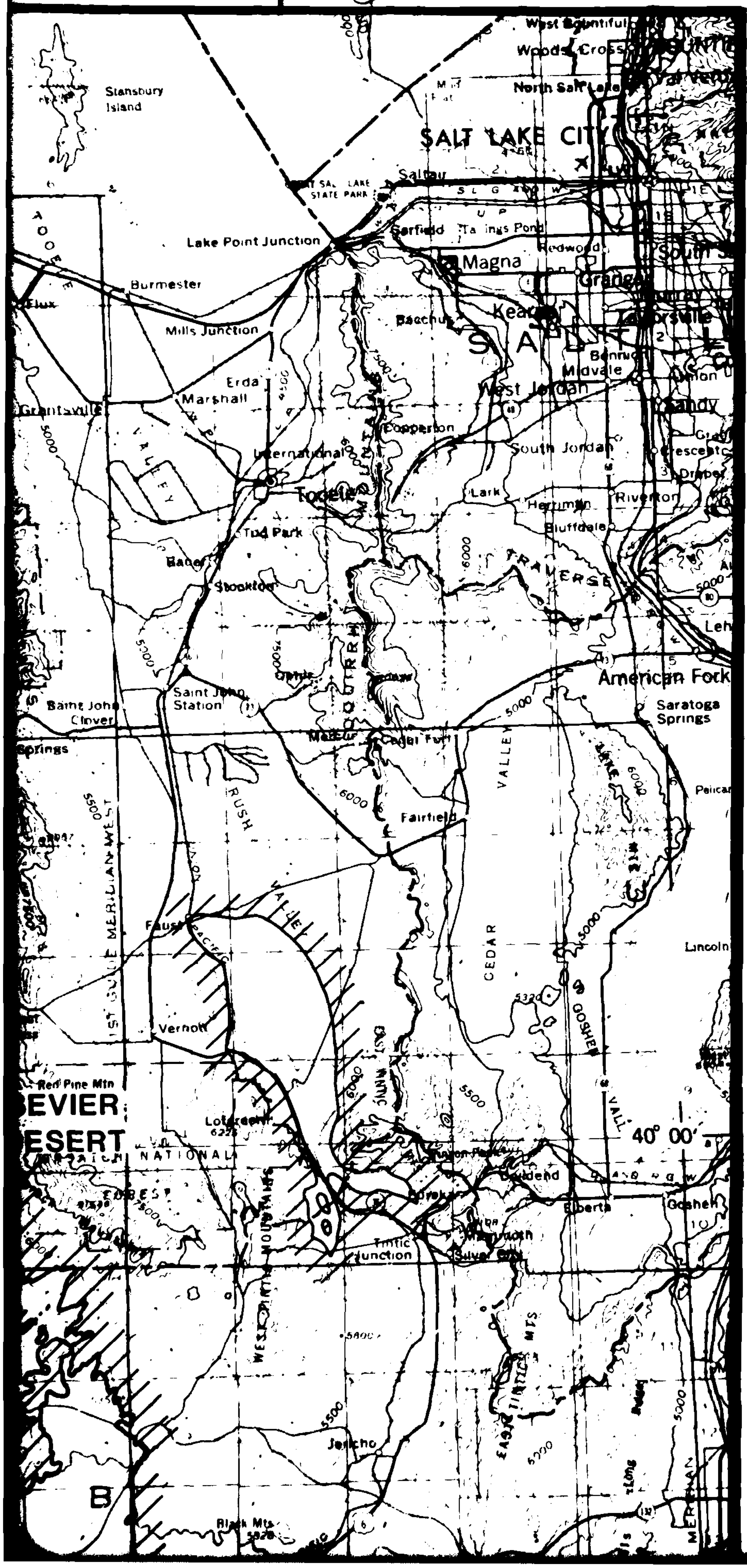

Stansbury Island
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Burmester
Mills Junction
Bacchus
Midvale
West Jordan
Erda
Marshall
Grantsville
Copperton
International
Tooele
South Jordan
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Lark
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Riverton
Bluffdale
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American Fork
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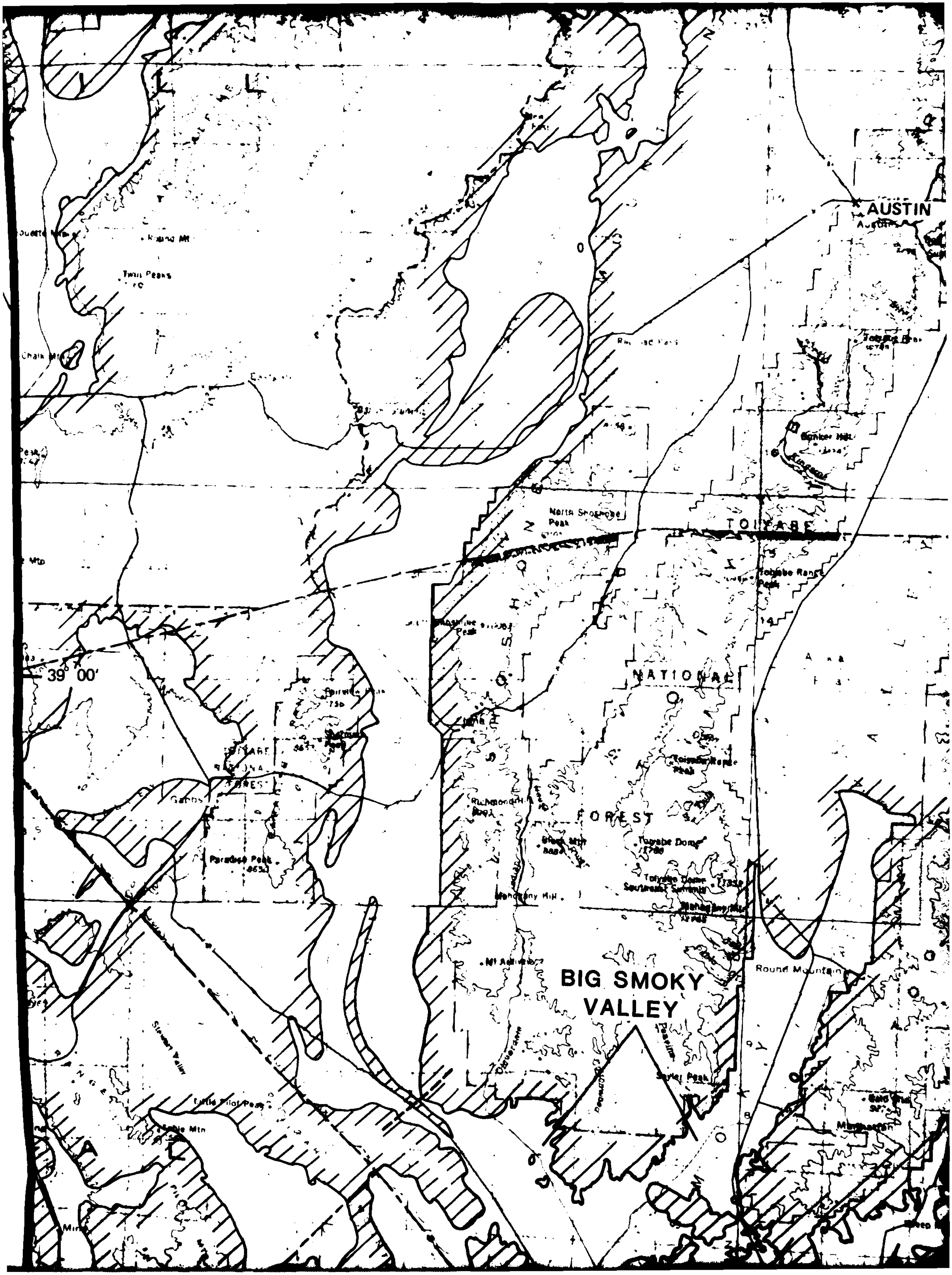

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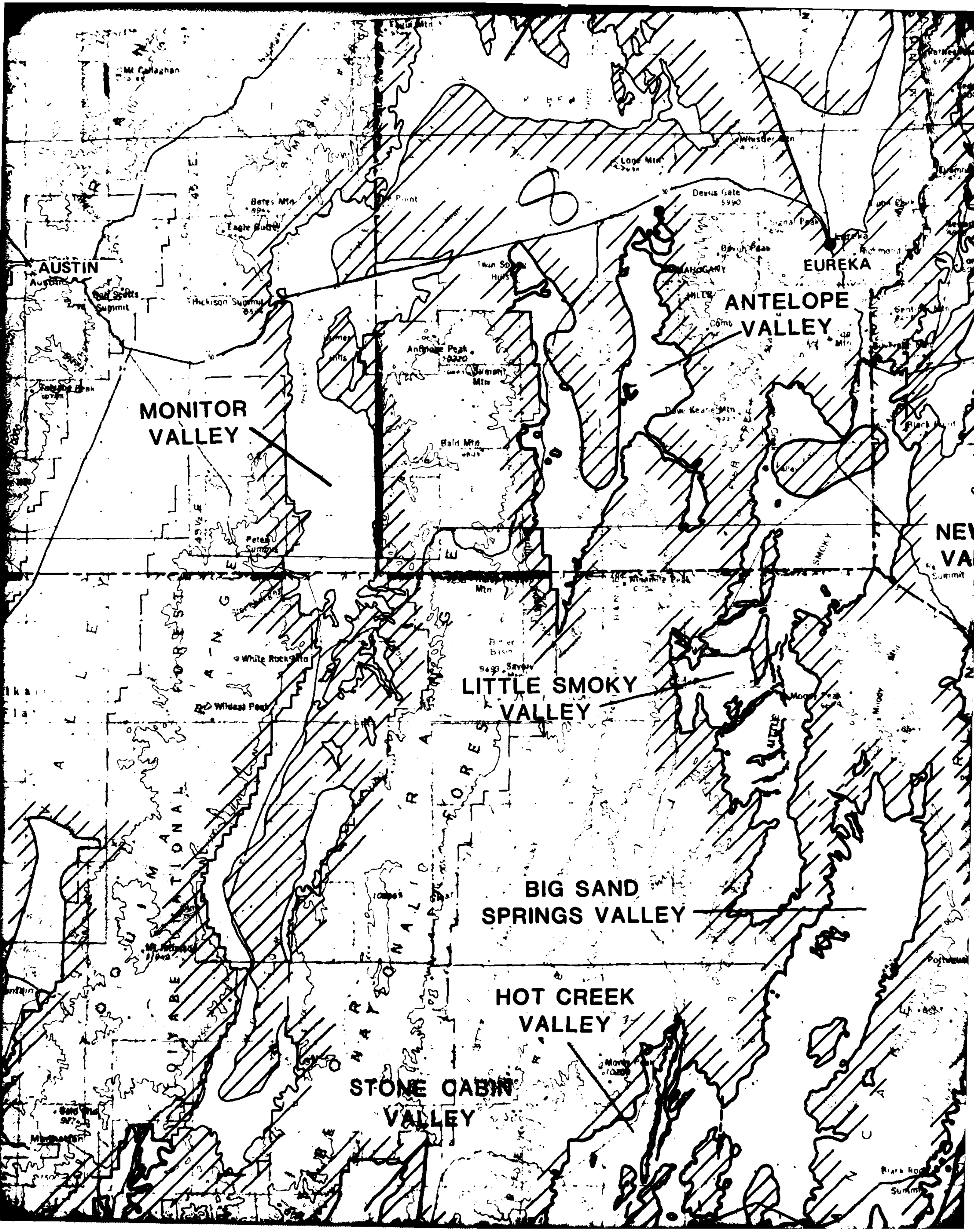
VALLEY
Round Mountain
Sayler Peak
Little Pilot Peak
Sable Mtn
Manhattan



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Antelope Peak
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Whistler Mtn
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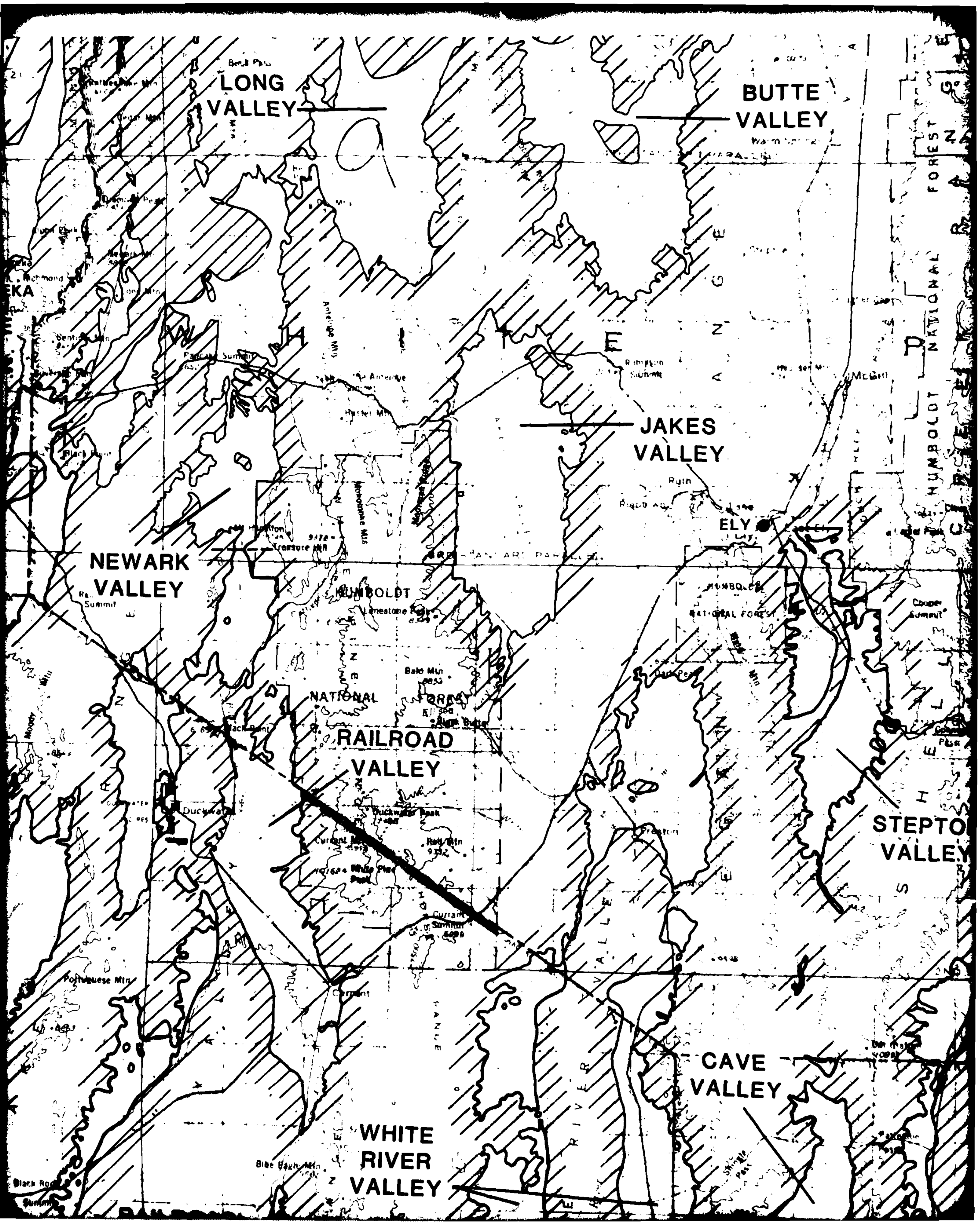
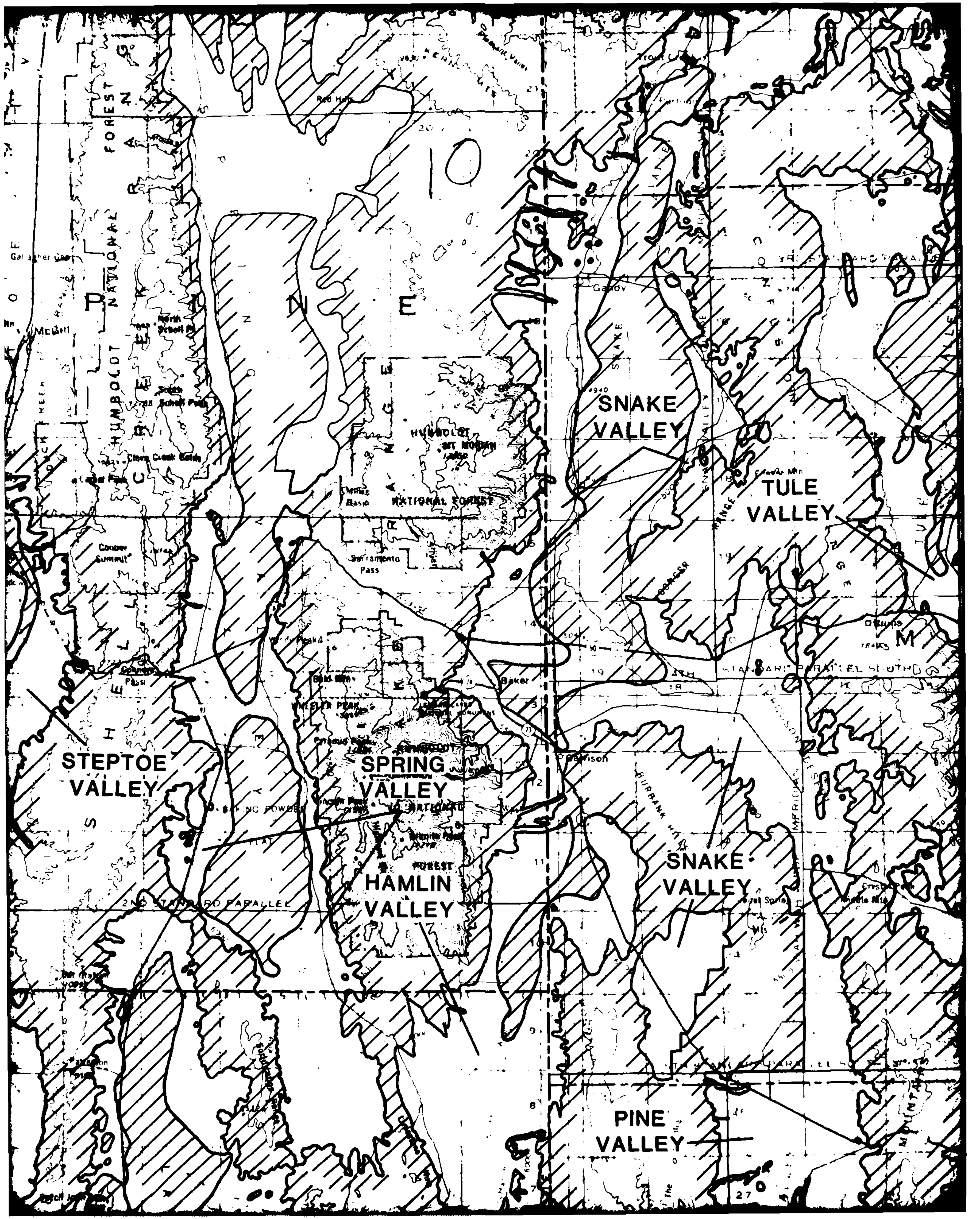
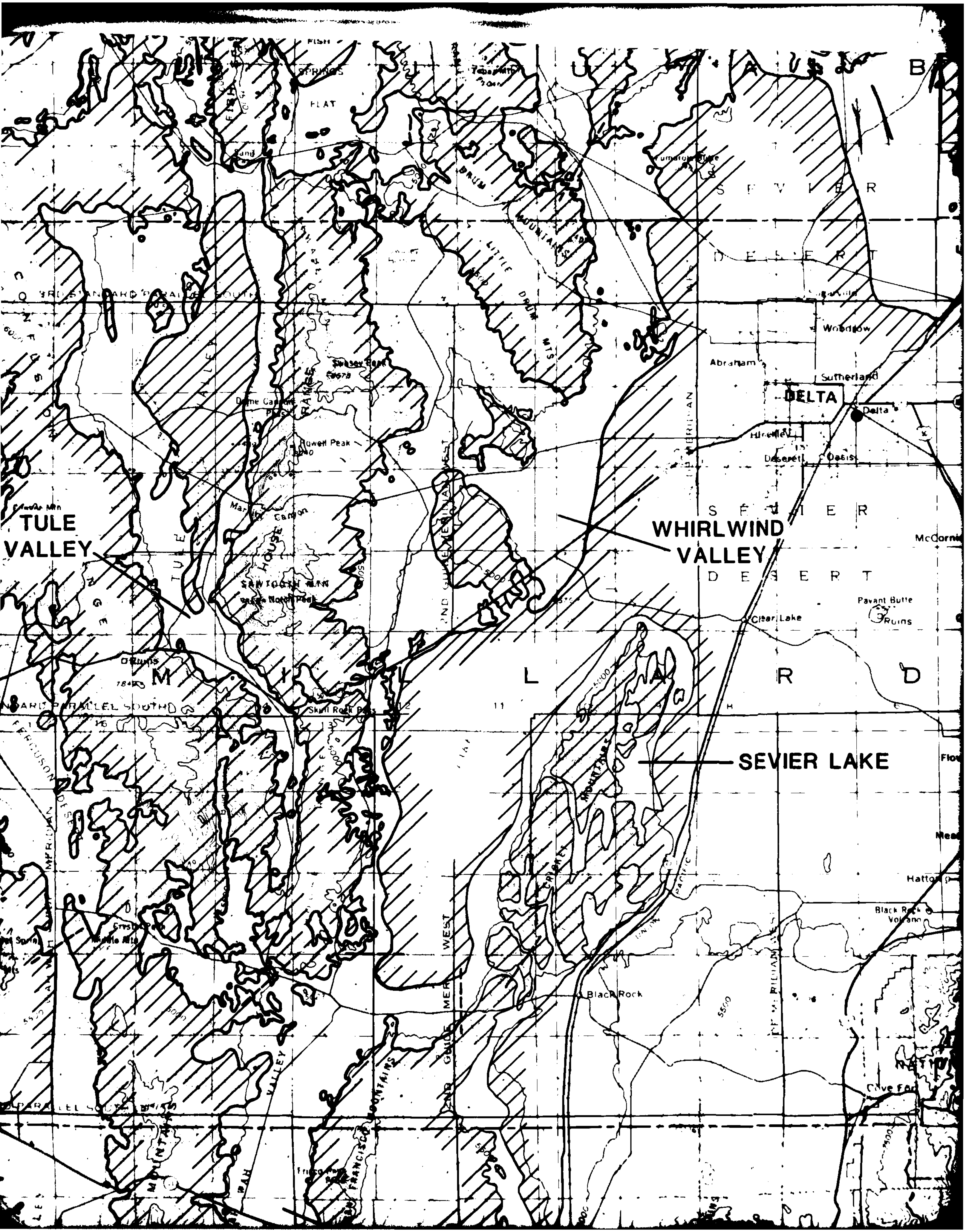
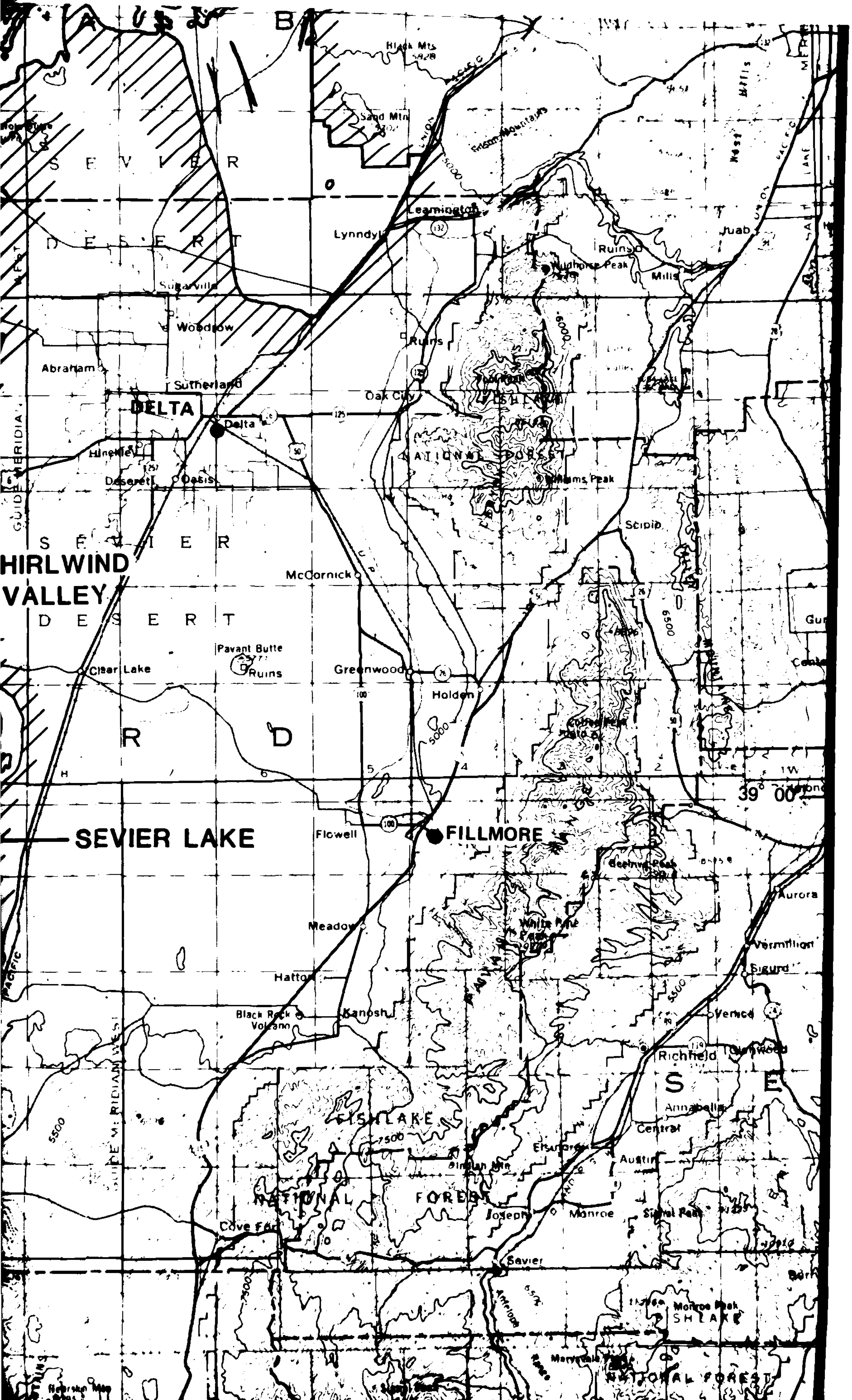
Eagle Butte
Mt Callaghan
Dave Keane Mtn
Wildcat Peak
White Rock Mtn
Pete Summit
Moody Peak
Bitter Basin



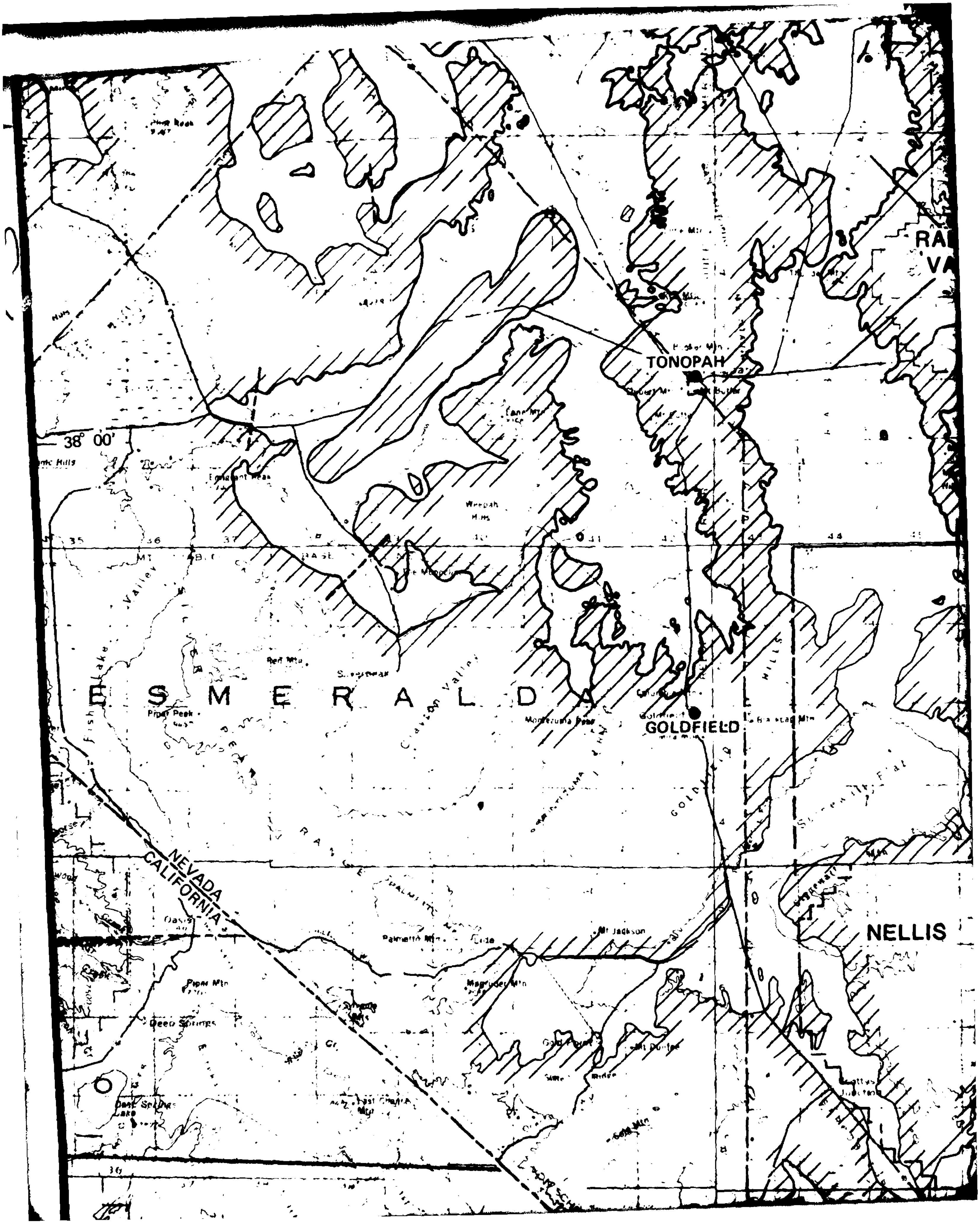
LONG VALLEY
BUTTE VALLEY
JAKES VALLEY
ELY
NEWARK VALLEY
RAILROAD VALLEY
STEPTO VALLEY
CAVE VALLEY
WHITE RIVER VALLEY
HUMBOLDT
NATIONAL FOREST
HUMBOLDT NATIONAL FOREST
Preston
Current
Currant Summit
Duckwater Peak
Portuguese Mtn


10
SNAKE VALLEY
TULE VALLEY
STEPTOE VALLEY
SPRING VALLEY
HAMLIN VALLEY
SNAKE VALLEY
PINE VALLEY
HUMBOLDT NATIONAL FOREST
Sacramento Pass
Baker
Garrison
Gandy
2ND STANDARD PARALLEL
4TH STANDARD PARALLEL SOUTH

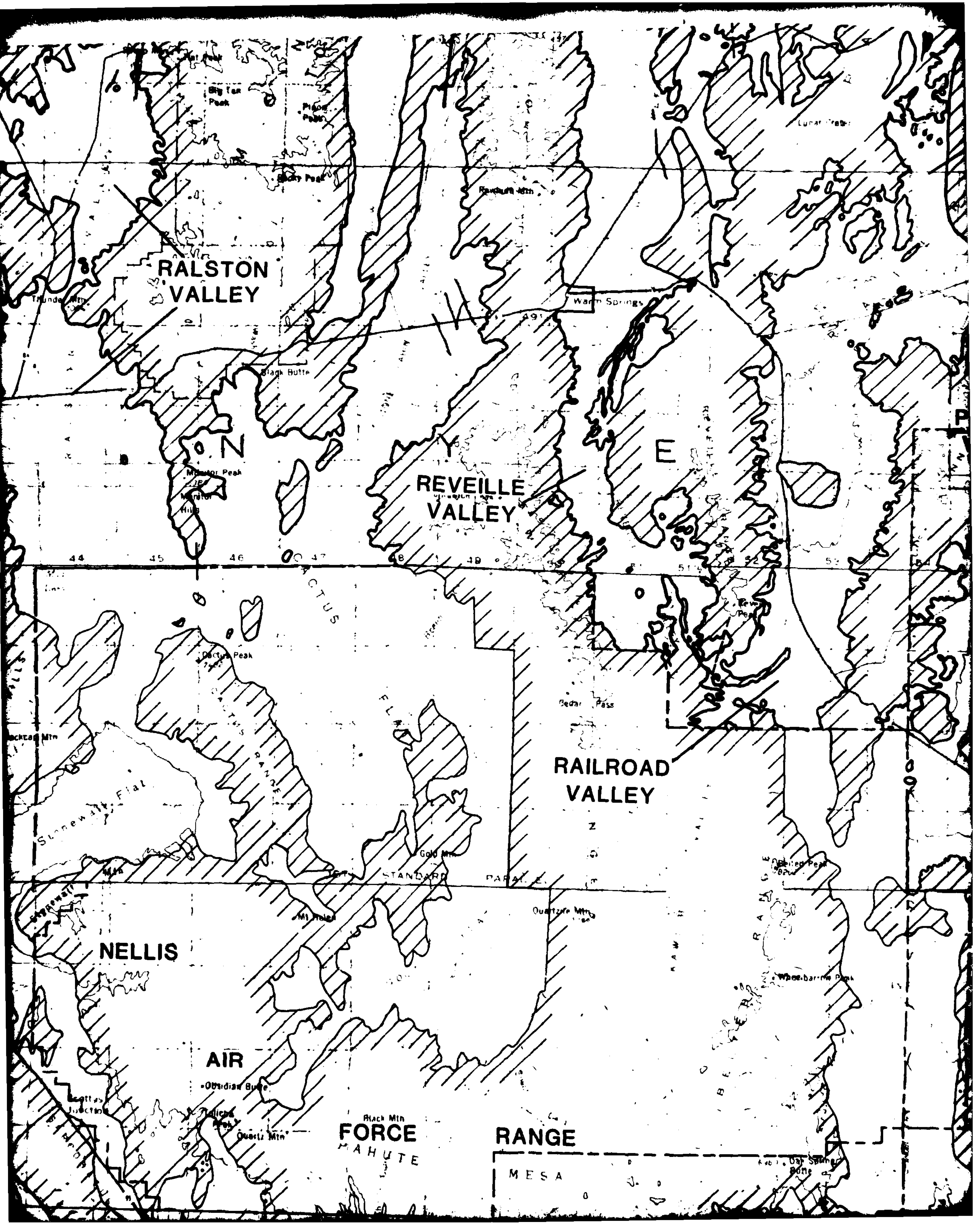

TULE
VALLEY
WHIRLWIND
VALLEY
SEVIER LAKE
DELTA
SEVIER
DESERT
SEVIER
DESERT
Delta
Sutherland
Woodrow
Abraham
Hinckley
Deseret
Oasis
Clear Lake
Pavant Butte
Black Rock
Black Rock Volcano
Hatton
Swasey Peak
Howell Peak
Marjum Canyon
Skull Rock Pass
HOUSE
TULE
LITTLE
DRUM
MTS
DRUM
MOUNTAINS
CRICKET
MOUNTAINS
FISH
SPRINGS
FLAT
WEST
VALLEY
SAN FRANCISCO
MOUNTAINS
Ruins


SEVIER DESERT
Black Mts
Sand Mtn
Leamington
Lynndyl
Juab
Ruins
Mills
Sugarville
Woodrow
Abraham
Sutherland
Oak City
DELTA
Delta
Hinckley
Deseret
Oasis
Williams Peak
Scipio
HIRLWIND VALLEY
McCornick
Pavant Butte
Ruins
Clear Lake
Greenwood
Holden
39° 00'
SEVIER LAKE
Flowell
FILLMORE
Aurora
Meadow
Vermillion
Sigurd
Hatton
Black Rock Volcano
Kanosh
Venice
Richfield
Glenwood
Annabella
Central
FISHLAKE
Elsinore
Austin
NATIONAL FOREST
Joseph
Monroe
Cove Fort
Sevier
Monroe Peak
FISHLAKE NATIONAL FOREST

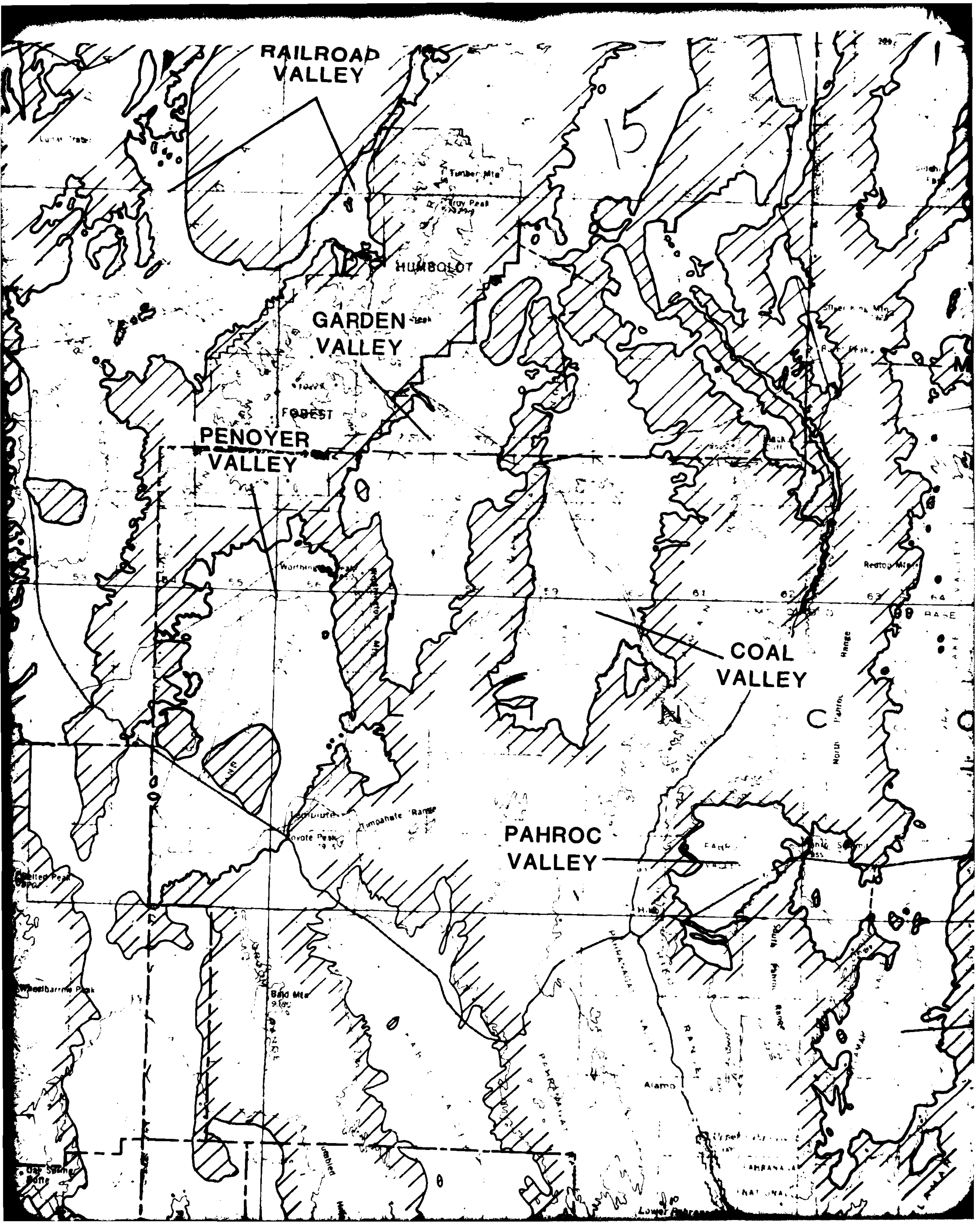
— 12



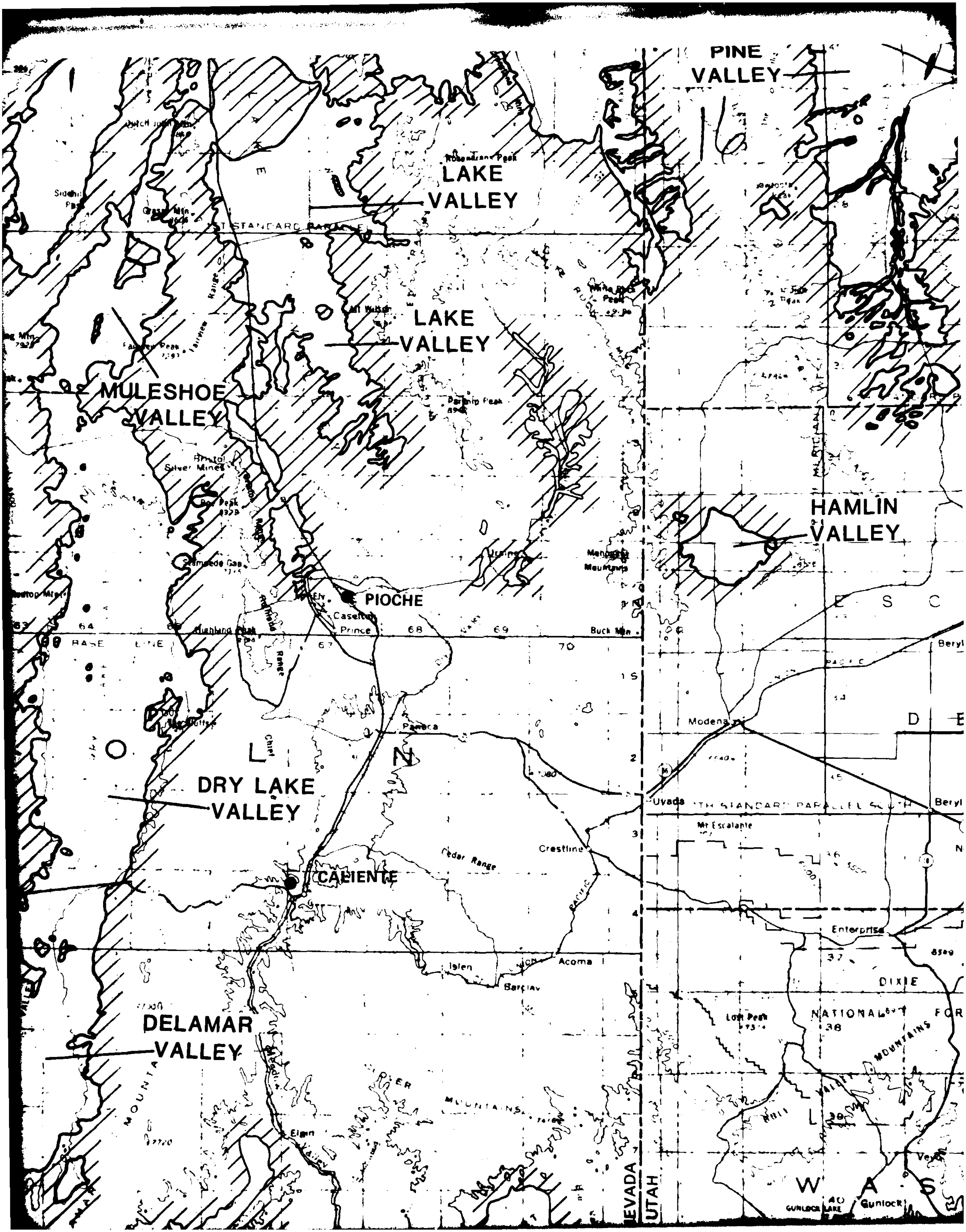
TONOPAH
GOLDFIELD
NELLIS
E S M E R A L D A
NEVADA
CALIFORNIA
38° 00'
Weepah Hills
Emigrant Peak
Red Mtn
Montezuma Peak
Fish Lake Valley
Clayton Valley
Piper Peak
Oasis
Palmetto Mtn
Lida
Mt Jackson
Magruder Mtn
Piper Mtn
Deep Springs
Gold Point
Mt Dunfee
Deep Springs Lake



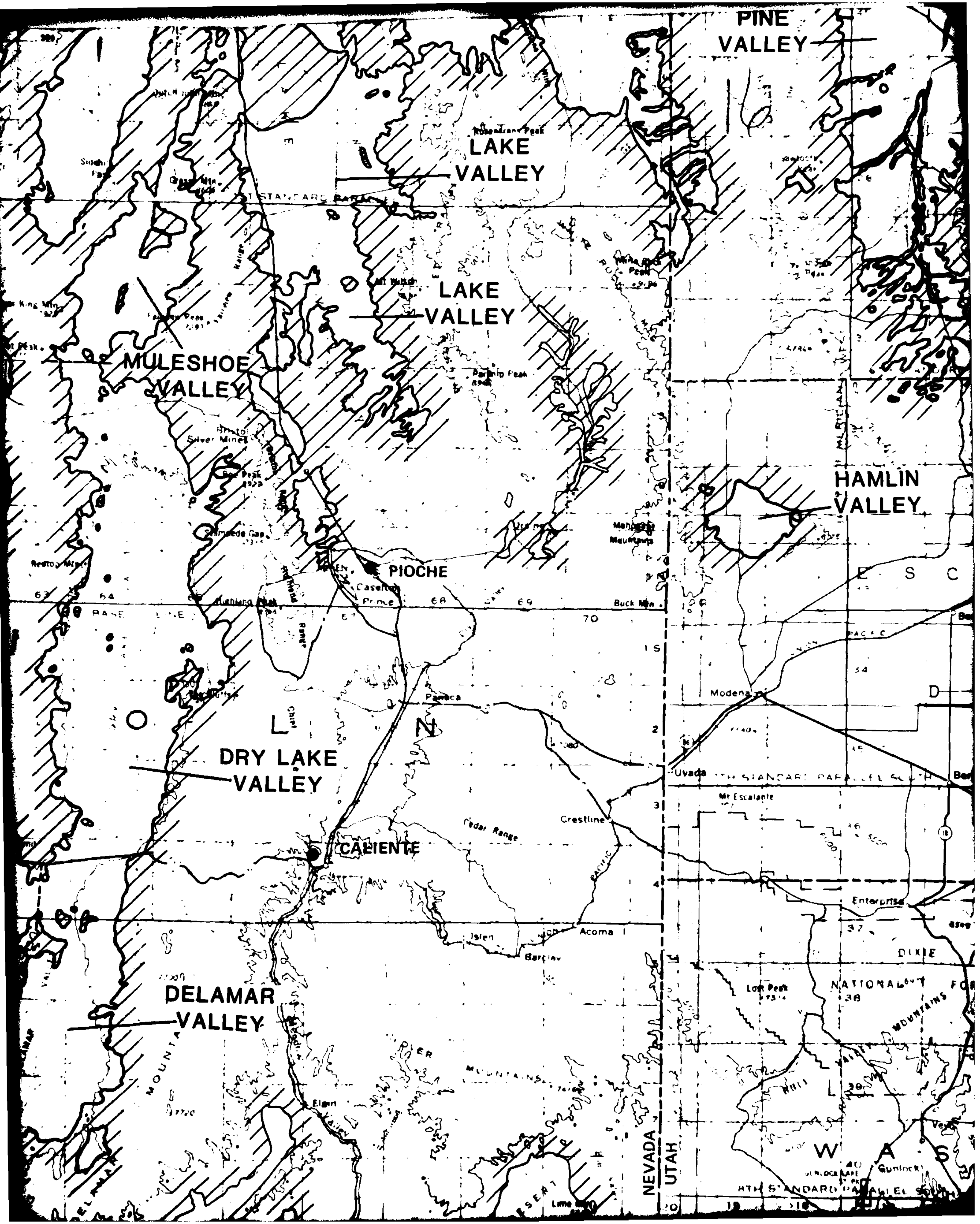
RALSTON VALLEY
REVEILLE VALLEY
RAILROAD VALLEY
NELLIS
AIR
FORCE
RANGE
Warm Springs
Black Butte
Monitor Peak
Cactus Peak
Cedar Pass
Gold Mtn
Quartzite Mtn
Obsidian Butte
Black Mtn
Quartz Mtn
Stonewall Flat
MESA
KAWICH RANGE
CACTUS RANGE
N
Y
E



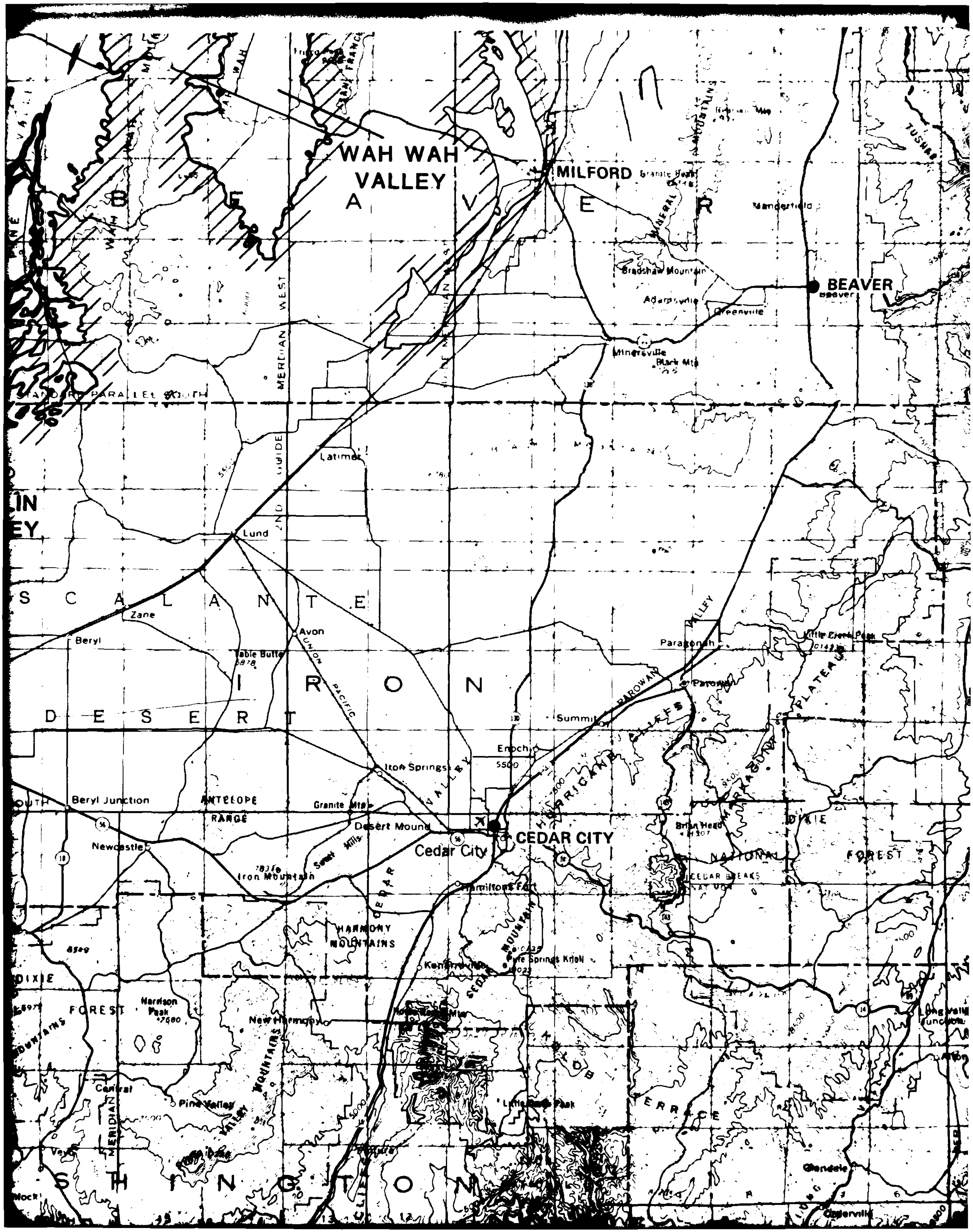
RAILROAD VALLEY
15
HUMBOLDT
GARDEN VALLEY
FOREST
PENOYER VALLEY
COAL VALLEY
PAHROC VALLEY
Alamo

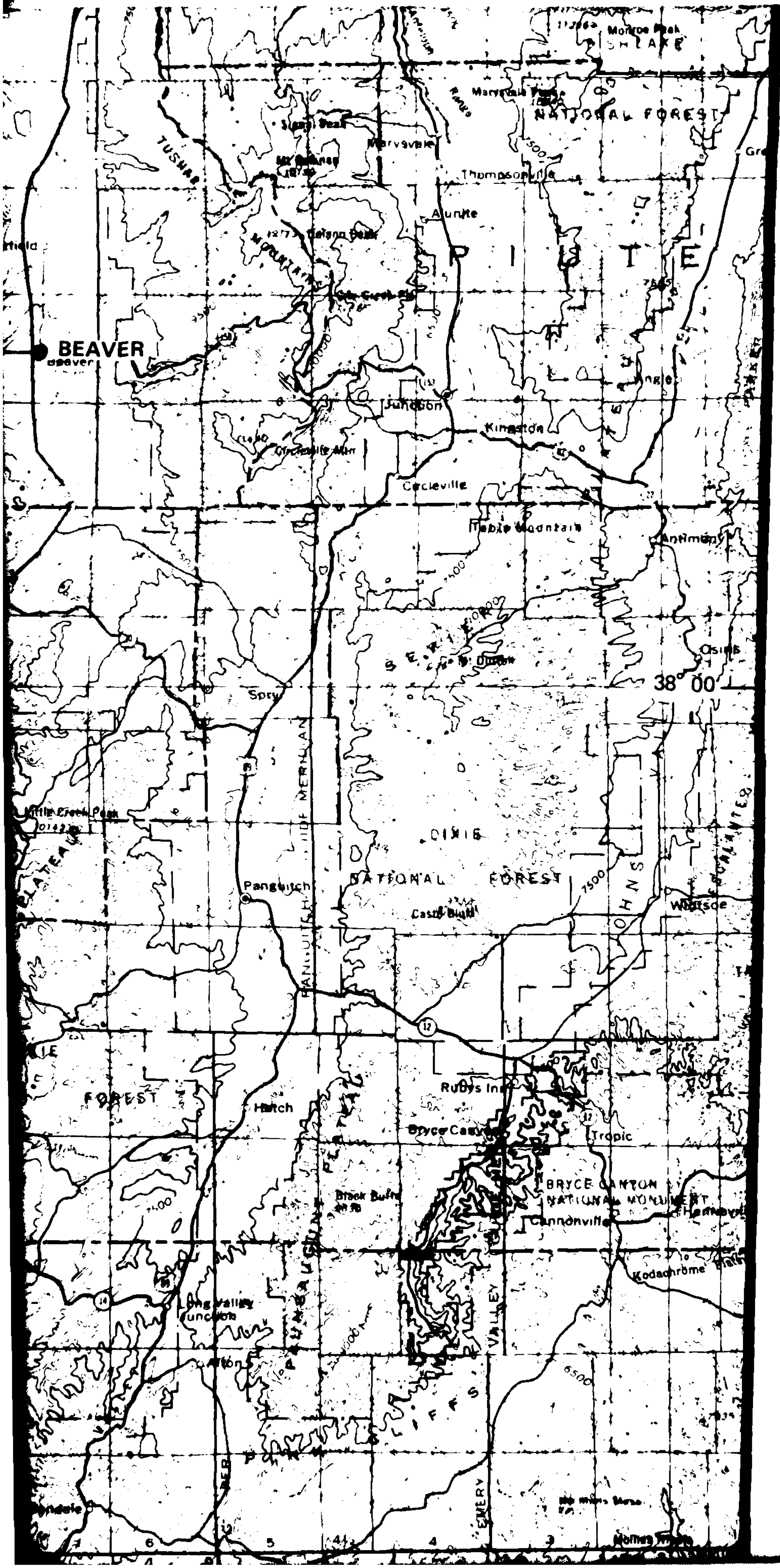


PINE VALLEY
LAKE VALLEY
LAKE VALLEY
MULESHOE VALLEY
HAMLIN VALLEY
PIOCHE
DRY LAKE VALLEY
CALIENTE
DELAMAR VALLEY
NEVADA
UTAH
Modena
Uvada
Crestline
Enterprise
Acoma
Caselton
Prince
Panaca
Beryl
Islen
Barclay
Elgin
Gunlock
Cedar Range
Bristol Silver Mines
Parsnip Peak
Highland Peak
Buck Mtn
Mt Escalante
Lost Peak
DIXIE
NATIONAL
BASE LINE



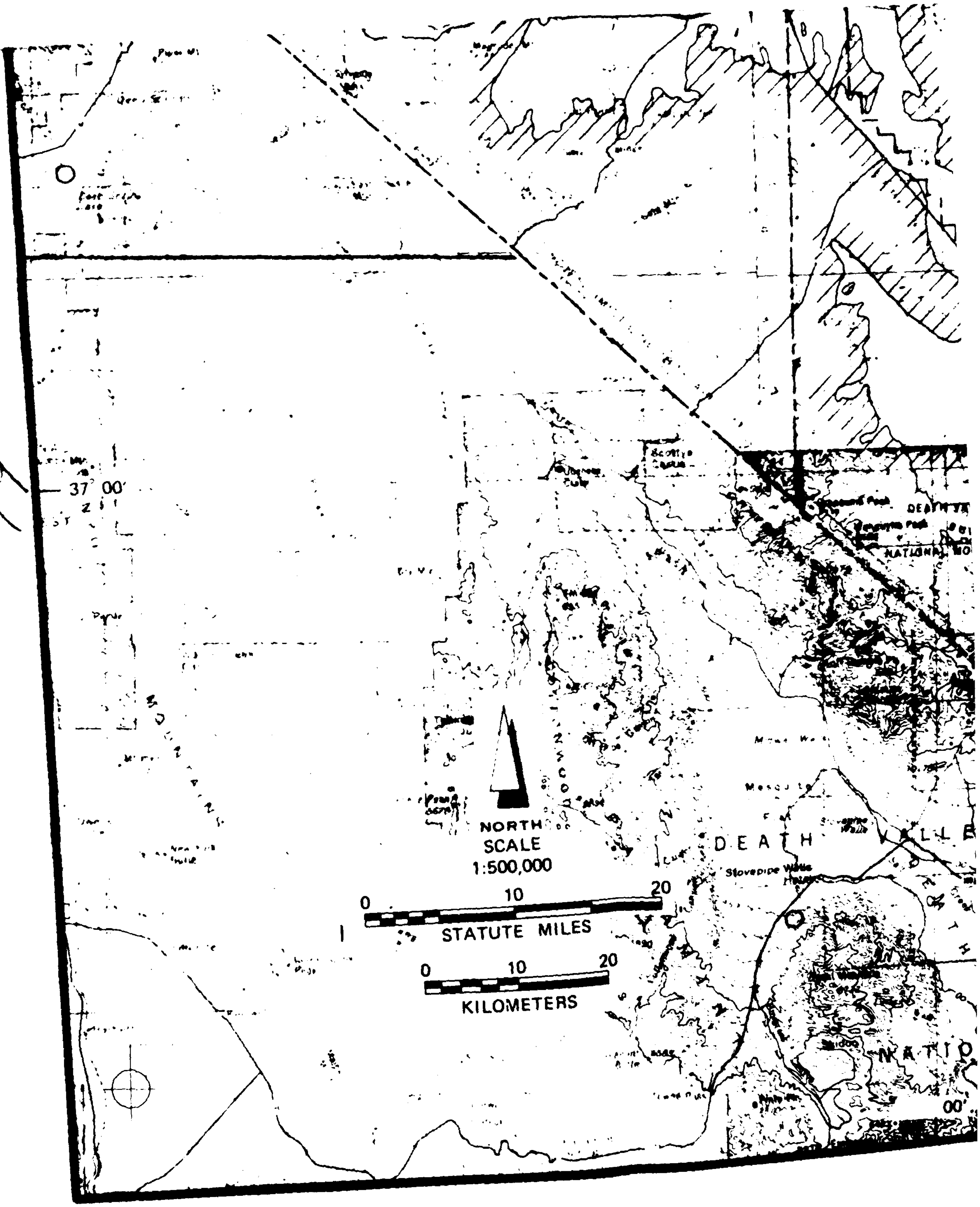
PINE VALLEY
LAKE VALLEY
LAKE VALLEY
MULESHOE VALLEY
HAMLIN VALLEY
PIOCHE
DRY LAKE VALLEY
CALIENTE
DELAMAR VALLEY
NEVADA
UTAH
Caselton
Modena
Uvada
Crestline
Enterprise
Acoma
Islen
Barclay
Elgin
Panaca
Buck Mtn
Mt Escalante
Lost Peak
Cedar Range
DIXIE
NATIONAL
Gunlock
Highland Peak
Parsnip Peak
Rosencrans Peak
Bristol Silver Mines


WAH WAH
VALLEY
MILFORD
BEAVER
Granite Peak
Mandersfield
Bradshaw Mountain
Adamsville
Greenville
Minersville
Black Mtn
Latimer
Lund
Zane
Beryl
Avon
Table Butte
UNION PACIFIC
S C A L A N T E
I R O N
D E S E R T
Paragonah
Parowan
Summit
Enoch
Iron Springs
Beryl Junction
ANTELOPE
RANGE
Granite Mtn
Desert Mound
CEDAR CITY
Cedar City
Newcastle
Iron Mountain
Hamiltons Fort
HARMONY
MOUNTAINS
Kanarraville
HURRICANE CLIFFS
CEDAR BREAKS
NATIONAL
FOREST
DIXIE
Little Creek Peak
PLATEAU
Brian Head
New Harmony
Harrison Peak
Central
Pine Valley
Glendale
Orderville
Long Valley Junction
W A S H I N G T O N
B E A V E R
LIN
EY

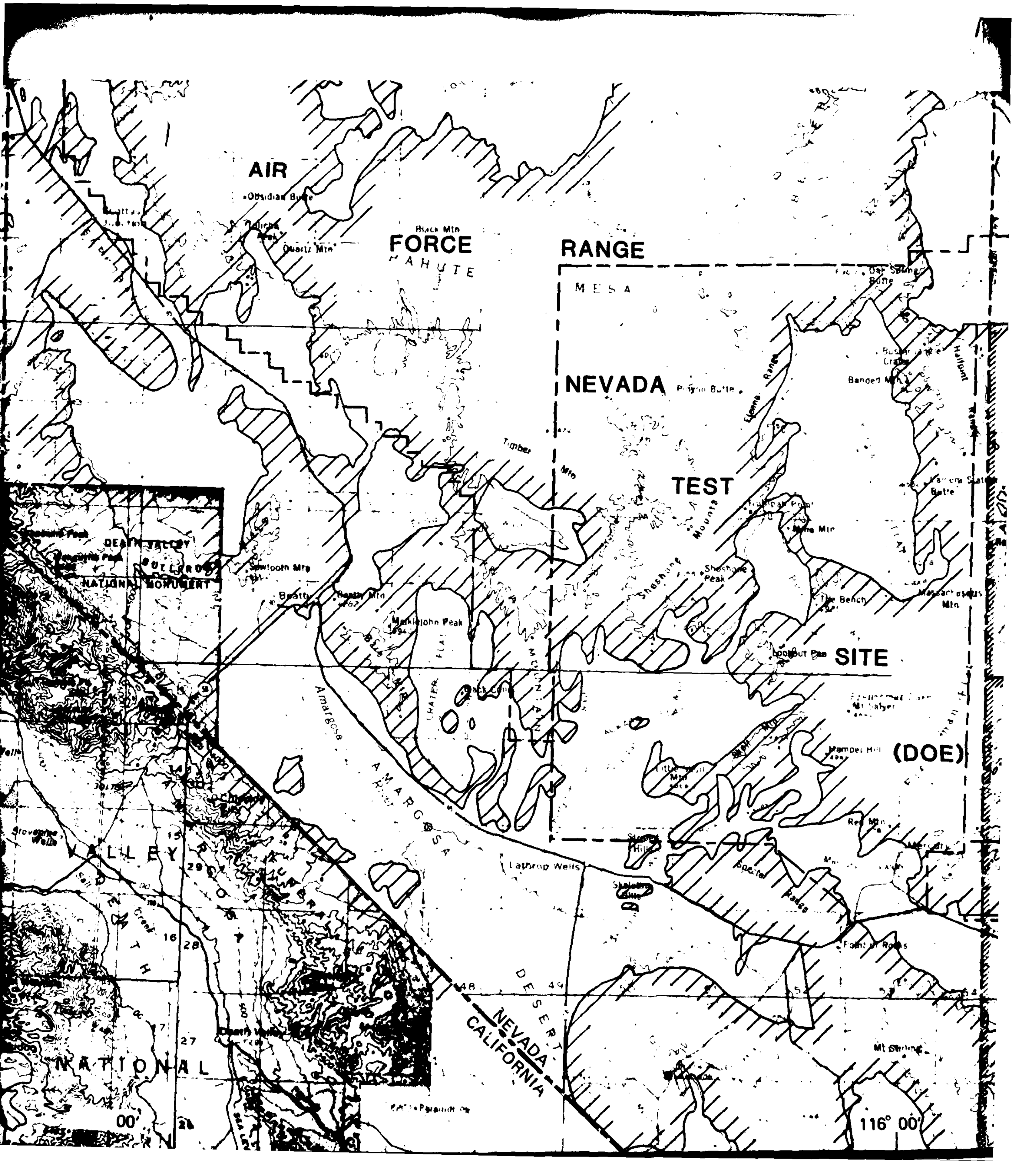

Monroe Peak
FISHLAKE
NATIONAL FOREST
Marysvale Peak
Signal Peak
Marysvale
TUSHAR
MOUNTAINS
Thompsonville
Alunite
Delano Peak
PIUTE
BEAVER
Beaver
Junction
Kingston
Angle
Circleville Mtn
Circleville
Table Mountain
Antimony
SEVIER
Osiris
38° 00'
Spry
Little Creek Peak
PLATEAU
DIXIE
NATIONAL FOREST
Panguitch
Castle Bluff
Widtsoe
JOHNS
ESCALANTE
12
Rubys Inn
FOREST
Hatch
Tropic
Bryce Canyon
BRYCE CANYON
NATIONAL MONUMENT
Black Butte
Cannonville
Henrieville
Kodachrome
14
Long Valley Junction
PAUNSAUGUNT
VALLEY
Alton
CLIFFS
6500
EMERY
PINK
Moquith
Mollies Nipple
3
6
5
4
3

18

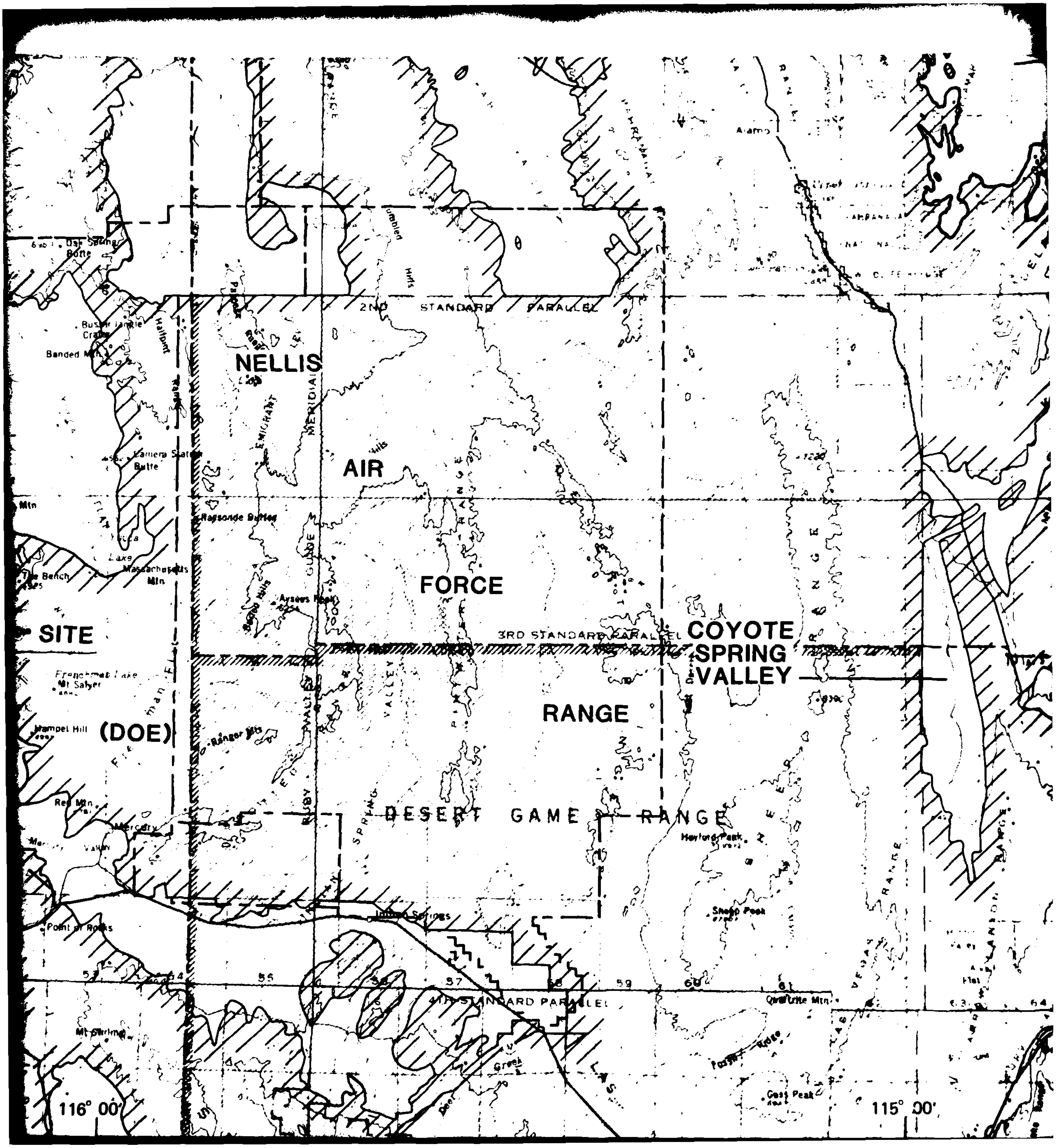
19



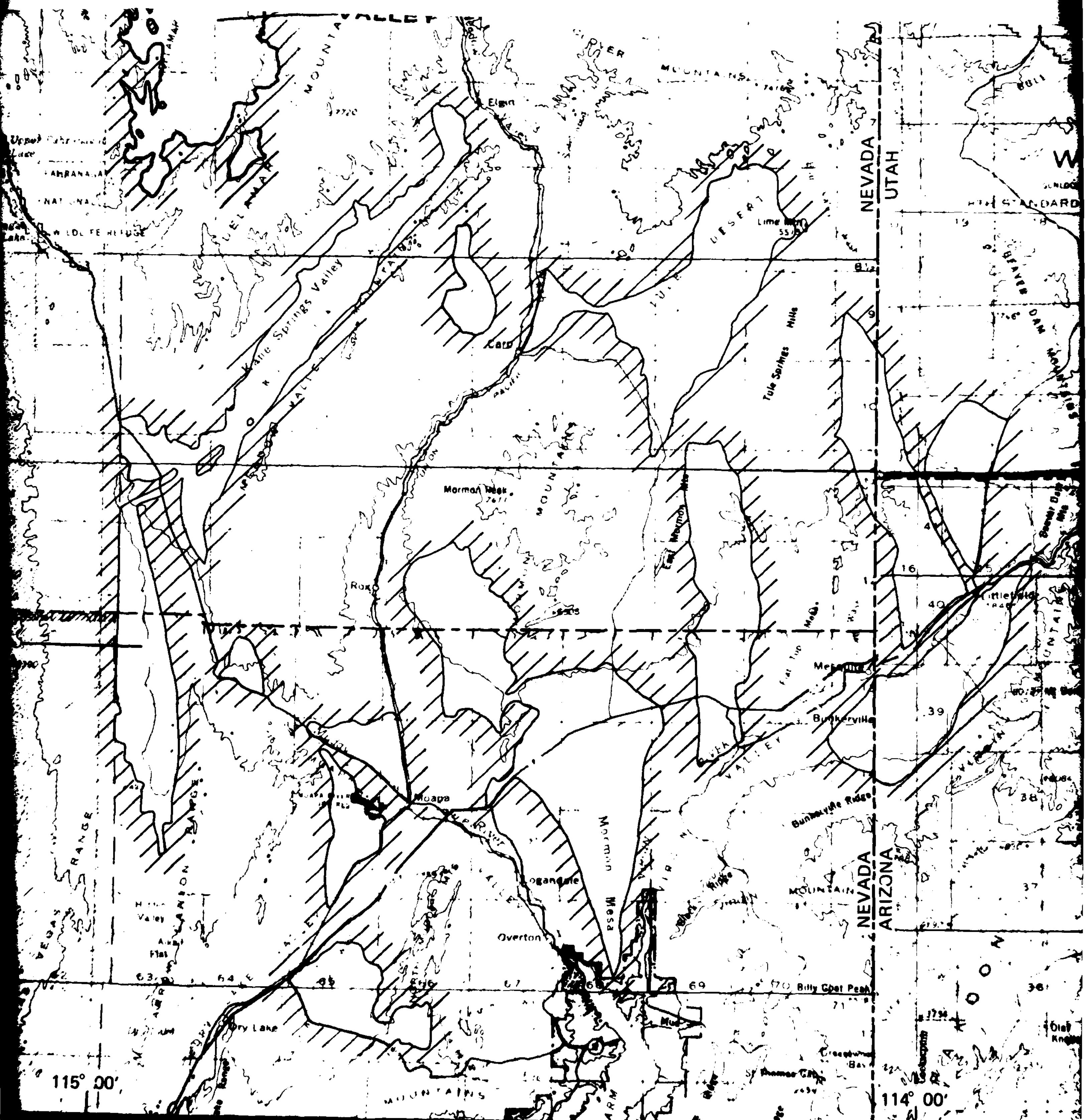
37° 00'
NORTH
SCALE
1:500,000
0
10
20
STATUTE MILES
0
10
20
KILOMETERS
DEATH
VALLE
Stovepipe Wells
00'



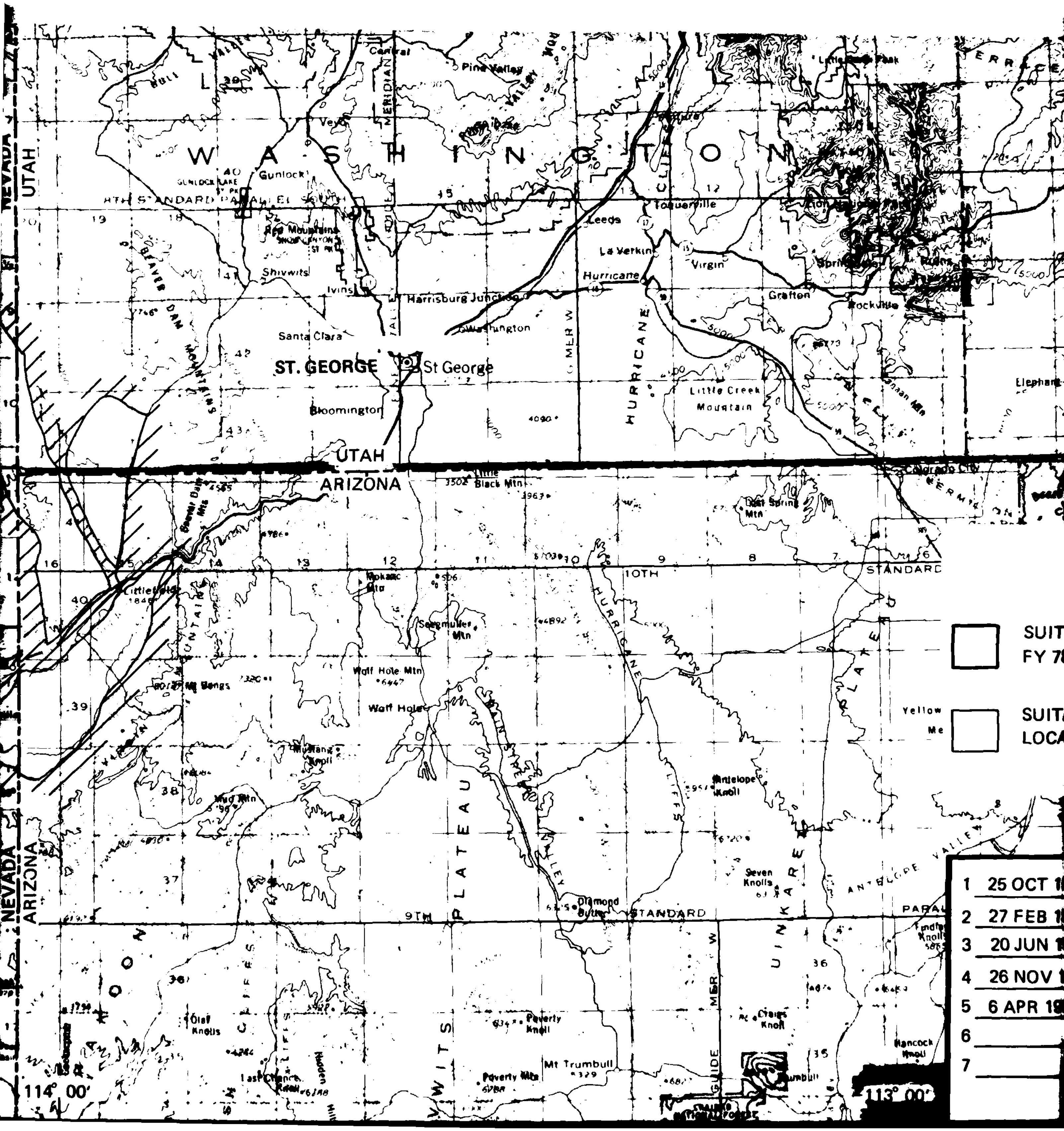
AIR
FORCE
RANGE
NEVADA
TEST
SITE
(DOE)
MESA
PAHUTE
Obsidian Butte
Black Mtn
Quartz Mtn
Pinyon Butte
Timber
Mtn
Shoshone Peak
Shoshone Mountain
Mine Mtn
The Bench
Massachusetts Mtn
Banded Mtn
Lookout Pk
Mt Salyer
Wahmonie
Skull Mtn
Little Skull Mtn
Red Mtn
Mercury
Specter Range
Point of Rocks
Mt Sterling
Stripped Hills
Lathrop Wells
Sawtooth Mtn
Beatty
Beatty Mtn
Meiklejohn Peak
Bare Mtn
Black Cone
CRATER FLAT
Amargosa
AMARGOSA DESERT
DEATH VALLEY
NATIONAL MONUMENT
VALLEY
NATIONAL
NEVADA
CALIFORNIA
Stovepipe Wells
116° 00'
00'
48
49
52
53
54

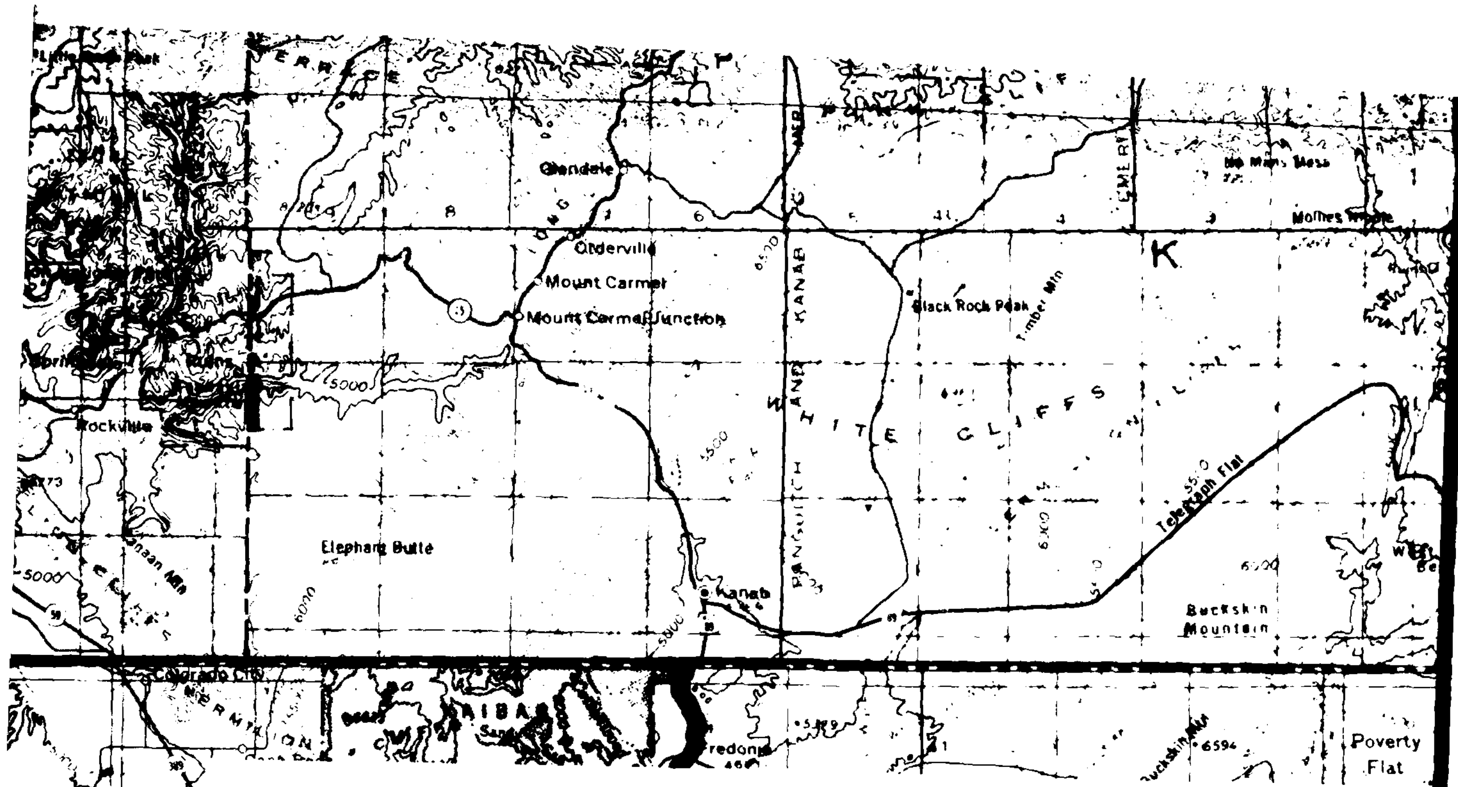


NELLIS
AIR
FORCE
RANGE
SITE
(DOE)
COYOTE
SPRING
VALLEY
DESERT GAME RANGE
2ND STANDARD PARALLEL
3RD STANDARD PARALLEL
4TH STANDARD PARALLEL
Alamo
Banded Mtn
Camera Station Butte
Massachusetts Mtn
Frenchman Lake
Red Mtn
Mercury
Point of Rocks
Indian Springs
Mt Stirling
Hayford Peak
Sheep Peak
Quartzite Mtn
Gass Peak
116° 00'
115° 00'



NEVADA
UTAH
Elgin
Lime Mtn
Kane Springs Valley
Carp
Tule Springs Hills
Mormon Peak
Rox
Moapa
Logandale
Overton
Mormon Mesa
Mesquite
Bunkerville
Bunkerville Ridge
Littlefield
Billy Goat Peak
Dry Lake
NEVADA
ARIZONA
115° 00′
114° 00′


NEVADA
UTAH
ARIZONA
W A S H I N G T O N
ST. GEORGE
St George
UTAH
ARIZONA
Central
Pine Valley
Veyo
Gunlock
Red Mountains
Shivwits
Ivins
Santa Clara
Bloomington
Harrisburg Junction
Washington
Leeds
Toquerville
La Verkin
Hurricane
Virgin
Grafton
Rockville
Springdale
Little Creek Mountain
Colorado City
Little Black Mtn
Littlefield
Wolf Hole Mtn
Wolf Hole
Seegmuller Mtn
Mokaac Mtn
Mustang Knoll
Mud Mtn
Antelope Knoll
Seven Knolls
Diamond Butte
Olaf Knolls
Last Chance
Poverty Knoll
Poverty Mtn
Mt Trumbull
Craigs Knoll
Hancock Knoll
Findlay Knolls
HURRICANE
CLIFFS
PLATEAU
ANTELOPE VALLEY
10TH STANDARD
9TH STANDARD
STANDARD
PARAL
MERIDIAN
GUIDE MER W
Yellow
SUITA
FY 78
SUITA
LOCA
1 25 OCT 1
2 27 FEB 1
3 20 JUN 1
4 26 NOV 1
5 6 APR 19
6
7
114° 00'
113° 00'



EXPLANATION

☐ SUITABLE AREA FOR HORIZONTAL SHELTER BASED ON VERIFICATION STUDIES· FY 78, FY 79 AND FY 80

Yellow ☐ SUITABLE AREA FOR HORIZONTAL SHELTER BASED ON SCREENING STUDIES. LOCALLY MODIFIED BY RECONNAISSANCE STUDIES

1	25 OCT 1979
2	27 FEB 1980
3	20 JUN 1980
4	26 NOV 1980
5	6 APR 1981
6	
7	

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MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE
BMO/AFRCE-MX

GEOTECHNICALLY
SUITABLE AREAS
NEVADA-UTAH

30 JUN 81

DRAWING 1-1

24

1

2.0 RESULTS AND CONCLUSIONS

2.1 SUITABLE AREA

The results of the interpretation of area suitable for deployment in Muleshoe Valley are listed in Table 2-1 and shown in map form in Drawing 2-1. The exclusion criteria used to make this interpretation are discussed in Appendix A2.0.

The total area of basin-fill materials in Muleshoe Valley is 111 square miles (mi^2) (287 square kilometers [km^2]). Thirty-two percent of this area is excluded for the horizontal shelter basing mode, leaving a suitable area of 76 mi^2 (197 km^2). For the vertical shelter basing mode, 35 percent of the total area is excluded, leaving a suitable area of 72 mi^2 (186 km^2). Detailed shelter layout studies show that, with 5200 feet (1585 m) between shelters, three clusters can be placed in Muleshoe Valley.

2.2 BASIN-FILL CHARACTERISTICS

This section contains brief descriptions of the soils in Muleshoe Valley. More detailed information is presented in Sections 3.3 and 3.4.

2.2.1 Surficial Soils

Coarse-grained granular soils are the predominant surficial soils, covering between 90 and 100 percent of the area. They consist of sandy and/or clayey gravels and gravelly, silty and/or clayey sands. Sandy gravels and gravelly sands are predominant in the central and southwestern portions of the valley.

VERIFICATION VALLEY	STATE	AREA MI ^{2} (KM ^{2})*		
		BEGINNING AREA	SUITABLE AREA	
			HORIZONTAL	VERTICAL
MULESHOE	NEVADA	111 (287)	76 (197)	72 (186)

EXCLUSIONS	AREA MI ^{2} (KM ^{2})	PERCENT REDUCTION**
< 50 FEET (15m) TO ROCK	23 (60)	21
< 150 FEET (46m) TO ROCK	27 (70)	24
< 50 FEET (15m) TO WATER	0 (0)	0
< 150 FEET (46m) TO WATER	0 (0)	0
TERRAIN***	12 (31)	11

* BEGINNING AREA COMPOSED OF BASIN–FILL MATERIALS EXCLUDING ALL ROCK OUTCROPS. ALL LARGE AREAS ARE ROUNDED OFF TO NEAREST ONE SQUARE MILE INCREMENT. METRIC CONVERSIONS ARE ROUNDED OFF TO NEAREST ONE SQUARE KILOMETER INCREMENT.

** PERCENT REDUCTIONS, BASED ON BEGINNING AREA, ARE ROUNDED OFF TO NEAREST WHOLE PERCENT. GROUND WATER DATA FROM FUGRO NATIONAL, INC. (1979).

*** TERRAIN EXCLUSIONS BETWEEN THE 50 FT. ROCK/WATER EXCLUSIONARY CONTOUR AND THE VALLEY BASIN FILL/ROCK CONTACT HAVE NOT BEEN CALCULATED.

Ertec The Earth Technology Corporation	MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE BMO/AFRCE-MX

ESTIMATED SUITABLE AREA
MULESHOE VALLEY, NEVADA

30 JUN 81 TABLE 2-1

In general, surficial soils grade to silty and/or clayey sands going down slope from the valley flanks toward the north-south valley axis. The soils are poorly to well-graded and have variable calcium-carbonate cementation.

Fine-grained soils cover no more than of 10 percent of the area. Typically, they occur along the central axis of the valley. They consist of sandy silts, sandy clays, and silty clays. Their plasticity ranges from nonplastic to slightly plastic.

2.2.2 Subsurface Soils

Soils in the subsurface are also predominantly coarse-grained, consisting of sandy gravels, gravelly sands, sands, silty sands, and clayey sands. Gravels and gravelly sands commonly occur along mountain fronts and grade to finer soils toward the valley axis. The coarse-grained soils are generally dense to very dense below 3 to 4 feet (0.9 to 1.2 m). They are poorly graded on the sides of the valley and well-graded along the axis of the valley. They contain coarse to fine sand and/or gravel, exhibit low compressibilities, and possess moderate to high shear strengths. Fine-grained soils (silts and clays) probably occur in less than 10 percent of the subsurface and are generally restricted to the central and northern portions of the valley. The fine-grained soils are nonplastic to slightly plastic with low to moderate compressibilities and shear strengths. Variable calcium-carbonate cementation exists in all the subsurface soils.

2.3 CONSTRUCTION CONSIDERATIONS

Geotechnical factors and conditions pertaining to construction of the MX system in suitable areas are discussed in this section. Both the horizontal shelter and vertical shelter basing modes are considered.

2.3.1 Grading

Mean surficial slopes in the suitable area are approximately three percent. Surface gradients between five and nine percent are present in about 20 percent of the suitable area. Therefore, preconstruction grading will be minimal for most of the valley. More extensive grading will be necessary along the western and northeastern portions of the valley where surface slopes range from five to nine percent.

The maximum grade at any shelter location in the layout planned for Muleshoe Valley would be between five and nine percent. For approximately 70 percent of the shelters, the grade would be less than five percent.

2.3.2 Roads

Where they are in a dense state, the predominant coarse-grained surficial soils will generally provide good subgrade support for roads. However, most of these soils exhibit low strength to an average depth of 3.3 feet (1.0 m). The subgrade supporting properties of these low-strength, coarse-grained soils are inadequate but they can be improved by mechanical compaction. Compaction to an average depth of 3.5 feet (1.1 m) appears to be

necessary in a majority of the suitable area. Compaction to greater depth may be required in approximately 15 to 25 percent of the granular soil area. Based on results of laboratory CBR tests, the in-situ granular soils, when compacted, will provide good to very good subgrade support for roads.

Fine-grained surficial soils exhibit low strength to an average depth of 13.6 feet (4.1 m), with a maximum depth of 20.0 feet (6.1 m). Supporting qualities of these soils in their natural state are inadequate for direct support of the base or subbase course of the road system. Results of laboratory CBR tests indicate that mechanical compaction will not adequately strengthen these fine-grained soils for direct support of the base course, but a select granular subbase layer over the compacted fine-grained surficial soils will give the required support.

Potential sources of aggregate suitable for use in road base and subbase courses have been identified in Pahroc Valley and are explained in detail in a report of the aggregate resources studies (Ertec, 1981. These studies indicate that aggregates potentially suitable for road construction are available in sufficient quantity in Muleshoe Valley.

Drainage incision depths are generally greater than 6 feet (1.8 m) within 85 to 95 percent of the suitable area. Therefore, the overall cost of drainage structures for roads will be moderate. The depth of incisions of the major drainages along the valley axis ranges from 10 to 25 feet (3.0 to 7.6 m).

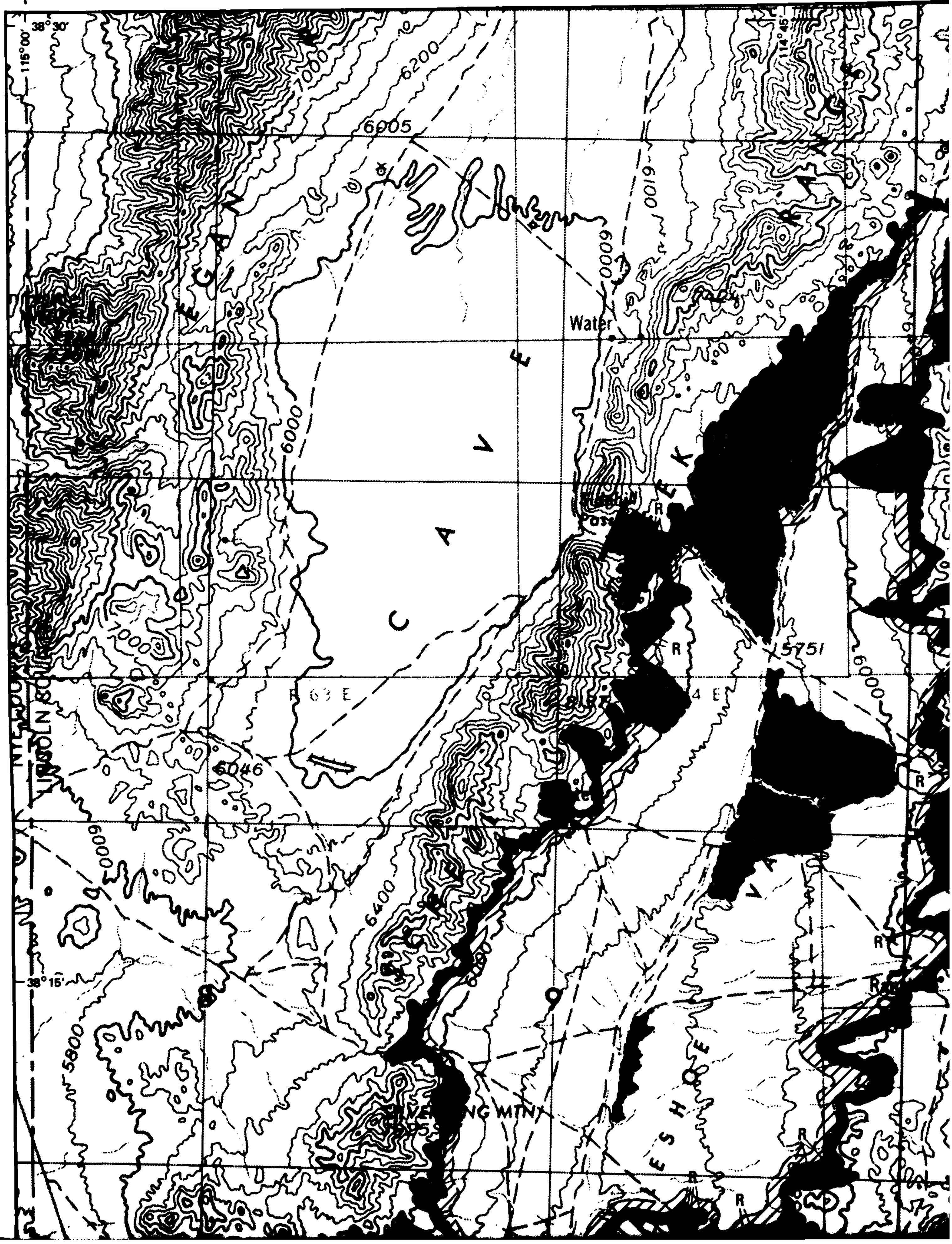
2.3.3 Excavatability and Stability

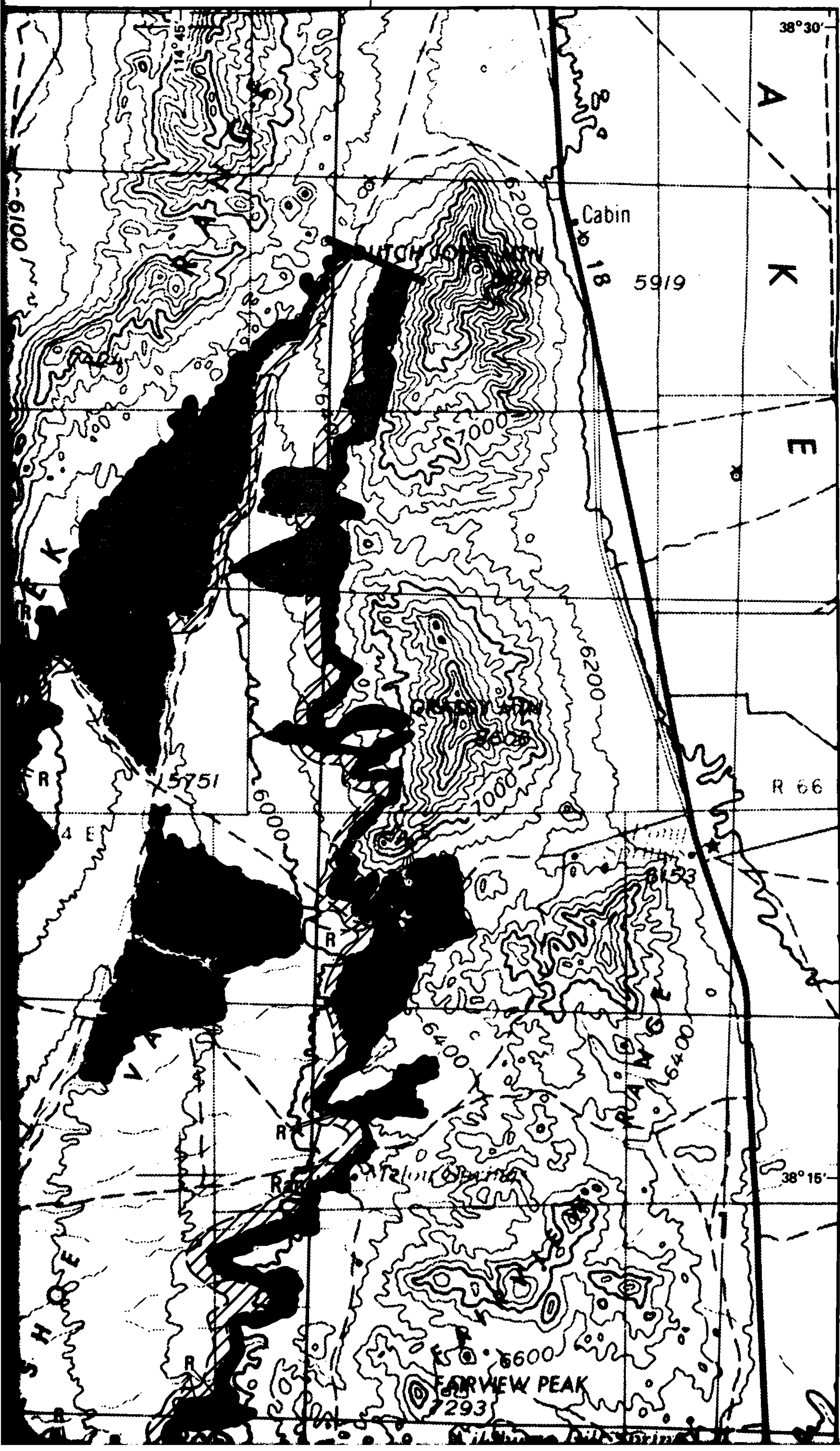
The soils in the construction zone are generally dense to very dense and possess various degrees of calcium-carbonate cementation.

Horizontal Shelter: Excavation for the horizontal shelter can be done using conventional equipment such as scrapers, backhoes, and bulldozers. Excavation will range from easy to moderately difficult in approximately 65 to 75 percent of the suitable area. However, excavation will be difficult in the remaining area due to cobbles, boulders, and strong calcium-carbonate cementation in the subsurface. Difficult excavation is generally limited to the areas adjacent to the mountain fronts in the vicinity of the central and southwestern portions of the valley. The soils investigation indicates that excavations for construction of shelters should be cut back to slopes ranging from 1/2:1 to 1 1/2:1 (horizontal:vertical) for stability. Variations in density and shear strength, which depend on soil composition and the degree of cementation, cause the wide variation in slope angle. Because of low-strength surficial soil, the top 2 to 4 feet (0.9 to 1.2 m) in all excavations will generally have to be cut back to a flatter slope.

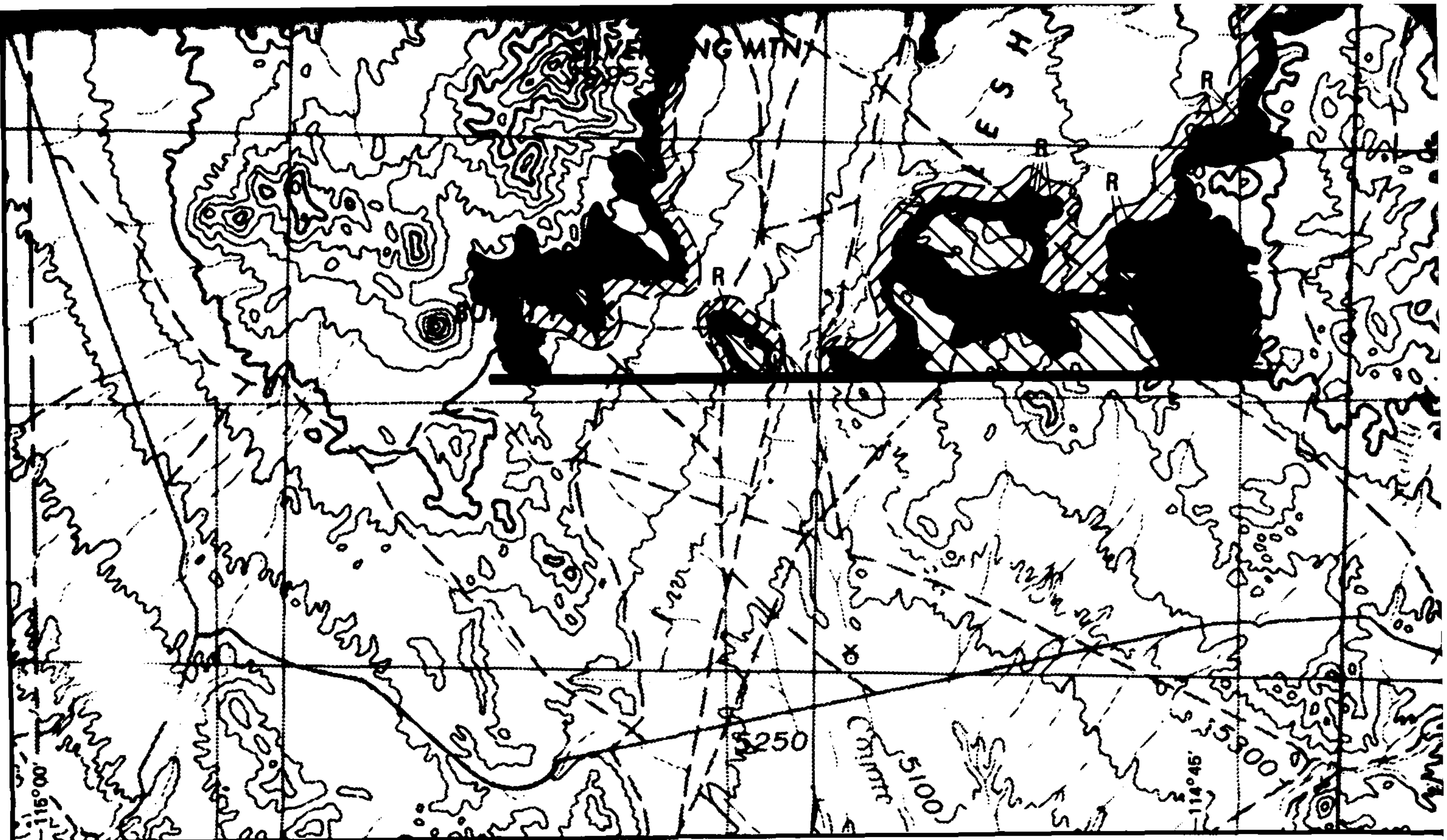
Vertical Shelter: Relatively low compressional wave velocities in the upper 120 feet (36 m) indicate that large diameter auger drills could be used for vertical shelter excavation. Most excavations will be in granular soils with only intermittent cemented or cohesive soil intervals. Therefore, the vertical

walls of these excavations probably will require the use of slurry or other stabilizing techniques in some cases.


38° 30'
115° 00'
6200
7000
6005
6100
6000
Water
6000
7000
R 63 E
4 E
5751
6046
6000
6400
6100
38° 15'
5800
NG MTN
114° 45'


38°30'
A
K
E
Cabin
18
5919
6200
7000
6200
R 66
5751
6000
6400
6400
38°15'
6600
FAIRVIEW PEAK
7293

E-TR-27-MS-I



EXPLANATION

Area suitable for horizontal and vertical shelter basing modes. Depth to rock and water greater than 150 feet (46m).

Area suitable for horizontal shelter but, not suitable for vertical shelter. Depth to rock greater than 50 feet (15m) and less than 150 feet (46m).

Area unsuitable for both horizontal and vertical shelter basing modes as determined from application of depth to rock and water, topography/terrain, and cultural exclusions.

Areas of isolated exposed rock.

R — Areas of isolated exposed rock too small for shading.

Contact between rock and basin-fill.

Valley borders.

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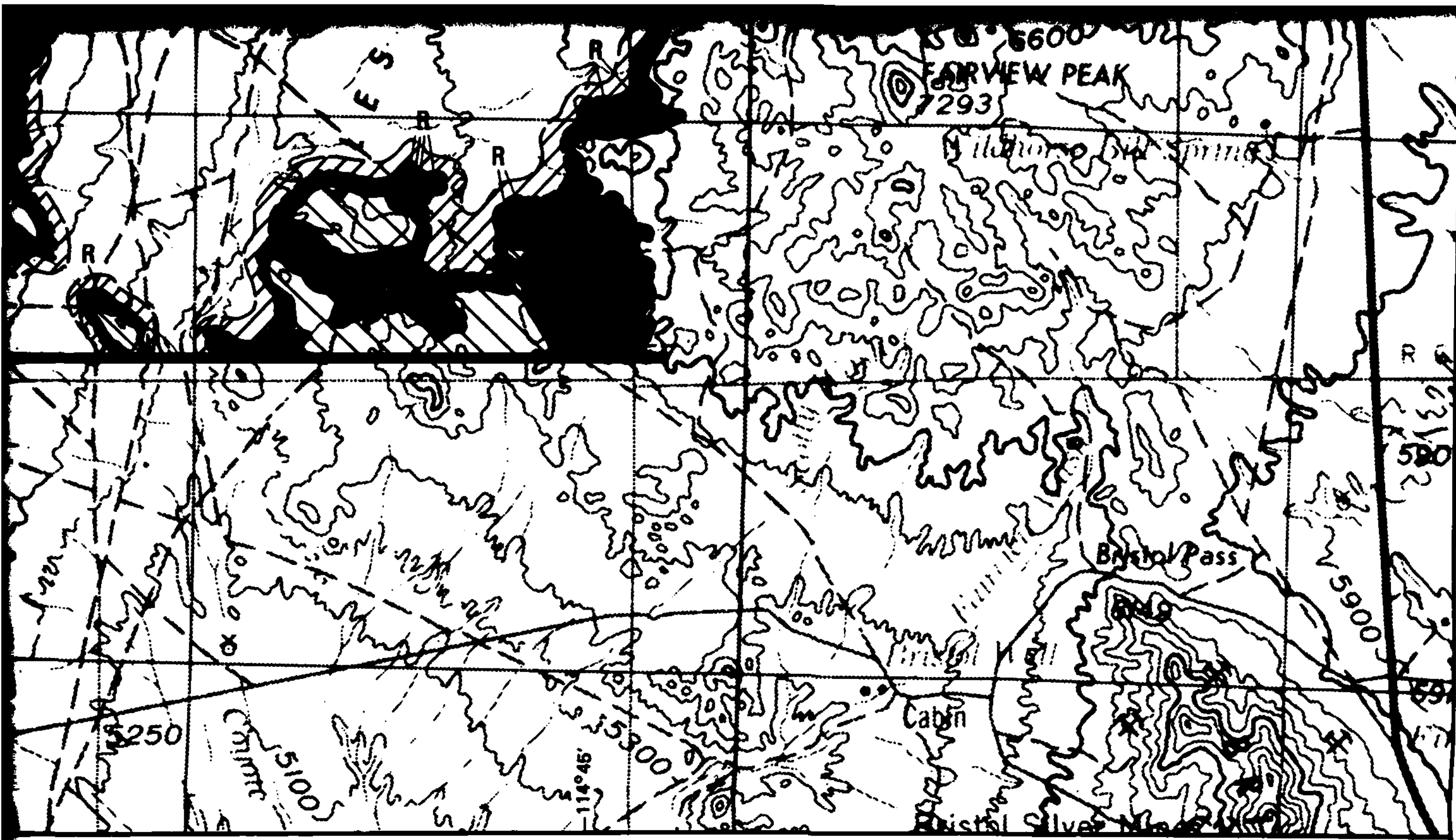
SUITABLE AREA
FOR HORIZONTAL AND VERTICAL SHELTERS
MULESHOE VALLEY, NEVADA

30 JUN 81

DRAWING 2-1



EXPLANATIO'I

iorizontal and vertical shelter basing modes. Depth to rock and water greater
n).

iorizontal shelter but, not suitable for vertical shelter. Depth to rock greater
) and less than 150 feet (46m).

r both horizontal and vertical shelter basing modes as determined from application
nd water, topography/terrain, and cultural exclusions.

xposed rock.

xposed rock too small for shading.

en rock and basin-fill.

NORTH

SCALE 1: 125,000

0 2 4
STATUTE MILES

0 2 4
KILOMETERS

3.0 GEOTECHNICAL SUMMARY

3.1 GEOGRAPHIC SETTING

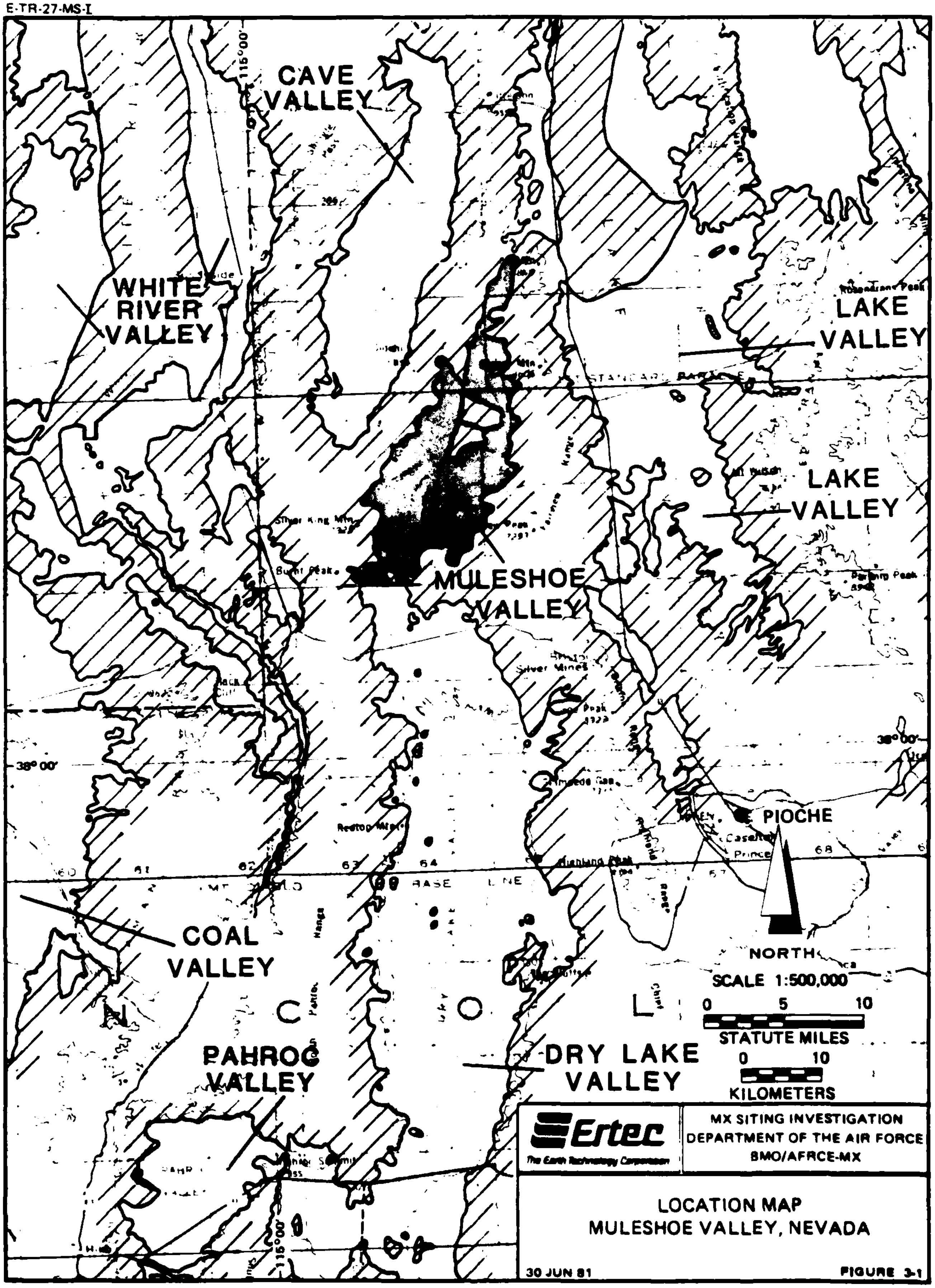
Muleshoe Valley (Figure 3-1) is located in northeastern Lincoln County, Nevada. The valley is bounded on the south by Dry Lake Valley, on the west by the southern portion of the Schell Creek Range, on the north by Lake Valley, and on the east, from north to south, by Dutch John Mountain, Grassy Mountain, and the Fairview Range. Main access to the valley is provided by Sidehill Pass and Cherry Creek Roads. A network of graded roads and jeep trails provide good access throughout the valley. The valley is primarily undeveloped desert rangeland, with scattered corrals, fencing, and water tanks. The Meloy Ranch and reservoir are located on the southeastern edge of the valley at Meloy Springs. Pioche, the nearest town, is approximately 32 miles (52 km) to the southeast.

3.2 GEOLOGIC SETTING

Geologic data stops and engineering field activities (Drawing 3-1) were used to verify the aerial photographic interpretation of geologic units.

3.2.1 Rock Types

Muleshoe Valley is a north-northeast trending alluvial basin. The Schell Creek Range to the west consists principally of Paleozoic sedimentary rocks (limestone, dolomite, quartzite, and shale) with some Tertiary volcanic rock (dacite) in the northern portion. The Fairview Range and the eastern bounding mountains consist principally of early Tertiary volcanic rocks overlying



LOCATION MAP
MULESHOE VALLEY, NEVADA

30 JUN 81

FIGURE 3-1

Paleozoic limestone and shale, particularly in the Grassy and Dutch John mountains.

3.2.2 Structure

Muleshoe Valley is part of a small, down-to-the-east tilted block that includes the southern Schell Creek Range. Sediments deposited on the down-tilted, eastern part of the block form the floor of Muleshoe Valley, whereas, the uptilted and emergent western part is the southern Schell Creek Range. A basin bounding fault is present on the east side of the valley and several faults and tectonic lineaments are located to the south (Drawing 3-2). In most cases, the faults have a northerly trend and appear to be normal faults typical of the Great Basin tectonic province.

The basin-bounding fault on the east side of Muleshoe Valley lies at the base of Dutch John Mountain. This fault corresponds to the eastern boundary of the Muleshoe tilt block and is probably responsible for eastward tilting and relative uplift of Dutch John Mountain. The age of this fault is uncertain but is probably Pliocene or younger. A more precise age cannot be determined because young geologic units which would bracket the age are not present over the trace of the fault.

Late Quaternary faults are present at the southwest end of Muleshoe Valley at Silver King Pass. These faults are located north of the intersection of several major, basin-bounding, normal faults at the junction of the Egan, Schell Creek, and North Pahroc ranges (Tschanz and Pampeyan, 1970). The Silver King

Pass faults appear to represent local readjustments to the stresses created at this intersection. They have vertical separations and in places cut Quaternary alluvium.

Although east-trending faults are generally older structural features related to pre-Basin and Range tectonics, Pliocene or younger movement is interpreted on an east-trending fault located about midway between Silver King and Sidehill passes. This fault has strong surface expression as a vegetation alignment on aerial photographs. It apparently has vertical separation.

A local zone of late Quaternary faults and related tectonic lineaments occurs in southern Muleshoe Valley. These features are primarily vegetation lineaments on aerial photographs although the faults have slight topographic relief. Both the faults and lineaments cut intermediate-age alluvial fan deposits (A5i) but are not believed to be major tectonic features because of their limited length and small displacements.

Low hills of volcanic bedrock separate southern Muleshoe Valley from northern Dry Lake Valley. This is reflected in the gravity data for Dry Lake Valley (Fugro National, Inc., 1980) and indicates that the Dry Lake graben is structurally separate from Muleshoe Valley.

3.2.3 Surficial Geologic Units

Alluvial fans of intermediate relative age (A5i) are the predominant surficial geologic unit within the valley (Drawing 3-2). These are composed of sandy gravels and gravelly sands near the

mountain fronts and silty and/or clayey sands near the center of the valley. There is a significant deposit of A5i silty gravel in the southwestern portion of the valley adjacent the drainage axis (Coyote Creek). Old-age alluvial fans are usually located near the mountain fronts but occasionally extend to the axial drainage in the northwestern portion of the valley. Holocene fluvial deposits (A1) are found in the axial drainage.

Surficial geologic units mapped in Muleshoe Valley (Drawing 3-2) consist of the following:

- Old-Age Alluvial Fan Deposits (A5o) - These Pleistocene age units are fairly extensive within the valley, occupying approximately 19 percent of the total valley area. The fans consist of sandy gravels, gravelly sands, silty sands, and poorly graded sands, generally occurring adjacent to the mountain fronts, although some exist in the central portion of the valley. Cementation ranges from none to strong, generally moderate; caliche development varies mainly from Stage III to IV.

- Intermediate-Age Alluvial Fan Deposits (A5i) - These fans, also of Pleistocene age, are the most extensive unit within the valley, occupying approximately 77 percent of the valley area. They occur from the base of the mountain fronts to the valley axial drainage. A significant area of the northwestern portion of the valley, and the higher elevations of these fans, are underlain by shallow rock. The unit consists of silty gravels to silty and clayey sands. Cementation varies from absent to strong, generally weak; caliche development varies from none to Stage IV, predominantly Stage II.

- Young-Age Alluvial Fan Deosits (A5y) - These Holocene sediments occupy less than one percent of the valley area. They occur as small outwash fans primarily along the eastern banks of the axial drainage. The unit consists primarily of silty sand although a few finer-grained fans do exist. Cementation is absent to weak; caliche development varies from none to Stage I.

- Fluvial and Associated Floodplain Deposits (A1, A2) - These sediments are of Quaternary age and cover approximately three percent of the total area. They occur along the valley axial drainage and in the channels of the major washes. In the northern portion of the valley, the sediments are generally silty and clayey. On the south, the sediments are generally

coarser and represented by poorly graded sands and silty sands. There is generally no cementation; caliche development is none to Stage I.

3.3 SURFACE SOILS

Surficial soils of Muleshoe Valley are predominantly coarse-grained. They range from gravels with traces to some fines to sands with some fines. Fine-grained soils (silts and clays) have a limited areal distribution, being confined generally to the northern washes and central axis of the valley. Soils from the predominant surficial geologic units (those estimated to cover at least five percent of the total area) can be combined into the following three categories based on their physical and engineering characteristics:

1. Sandy gravels, clayey gravels, and gravelly sands (geologic units A5ig, A5is, and A5os);
2. Silty sands and clayey sands (geologic units A5is and A5os); and
3. Sandy silts, sandy clays, and silty clays (geologic units A5os).

3.3.1 Characteristics

A summary of the characteristics of surficial soils, based on field and laboratory test results, is presented in Table 3-1. In addition to the physical properties, the table includes road design data, consisting of laboratory compaction and CBR test results and thicknesses of low-strength surficial soils; and a qualitative assessment of the soils suitability for road use.

Gradation ranges for the three categories of surficial soils are shown in Figure 3-2. The surficial soils in the top 2 feet

SOIL DESCRIPTION		Sandy Gravels, Clayey Gravels and Gravelly Sands	Silty Sands and Cl
USCS SYMBOLS		GP, GM, GC, SW, SM	SM, SC
PREDOMINANT SURFICIAL GEOLOGIC UNITS		A5ig, A5is, A5os	A5is, A5os
ESTIMATED AREAL EXTENT %		10 - 20	75 - 85
PHYSICAL PROPERTIES			
COBBLES 3 – 12 inches (8 – 30 cm) %		0 - 5	0 - 5
GRAVEL %		16 - 60 [8]	0 - 19
SAND %		19 - 71 [8]	44 - 69
SILT AND CLAY %		5 - 35 [8]	30 - 38
LIQUID LIMIT		32 - 33 [2]	30
PLASTICITY INDEX		NP - 12 [3]	NP - 14
ROAD DESIGN DATA			
MAXIMUM DRY DENSITY pcf (kg/m^3)		119.0 - 131.5 (1906 - 2106) [3]	NDA
OPTIMUM MOISTURE CONTENT %		9.0 - 12.5 [3]	NDA
CBR AT 90% RELATIVE COMPACTION %		9 - 58 [3]	NDA
SUITABILITY AS ROAD SUBGRADE (1)		good to very good	fair to good
SUITABILITY AS ROAD SUBBASE OR BASE (1)		poor to good	poor to fair
THICKNESS OF LOW STRENGTH SURFICIAL SOIL (2)	RANGE ft (m)	0.7 - 1.4 (0.2 - 0.4) [9]	0.9 - 14.0 (0.3 - 4.3)
	AVERAGE ft (m)	1.1 (0.3) [9]	3.8 (1.2)

(1) Suitability is a subjective rating explained in Section A5.0 of the Appendix.

(2) Low strength surficial soil is defined as soil which will perform poorly as a road subgrade at its present consistency; see Table 3-2 for details.

NOTES:
- [ ] - (
- NDA – No
  not

Silty Sands and Clayey Sands	Sandy Silts, Sandy Clays and Silty Clays	
SM, SC	ML, CL	
A5is, A5os	A5os	
75 - 85	0 - 10	
0 - 5	0 - 5	
0 - 19 [3]	0 - 2 [5]	
44 - 69 [3]	6 - 41 [5]	
30 - 38 [3]	58 - 94 [5]	
30 [1]	25 - 33 [3]	
NP - 14 [2]	NP - 15 [6]	
NDA	114.0 (1826) [1]	
NDA	15.0 [1]	
NDA	4 [1]	
air to good	poor	
poor to fair	not suitable	
0.9 - 14.0 (0.3 - 4.3) [9]	0.5 - 20.0 (0.2 - 6.1) [6]	
13.8 (1.2) [9]	13.6 (4.1) [6]	

S: • [ ] – Number of tests performed.

• NDA – No data available (insufficient data or tests not performed)

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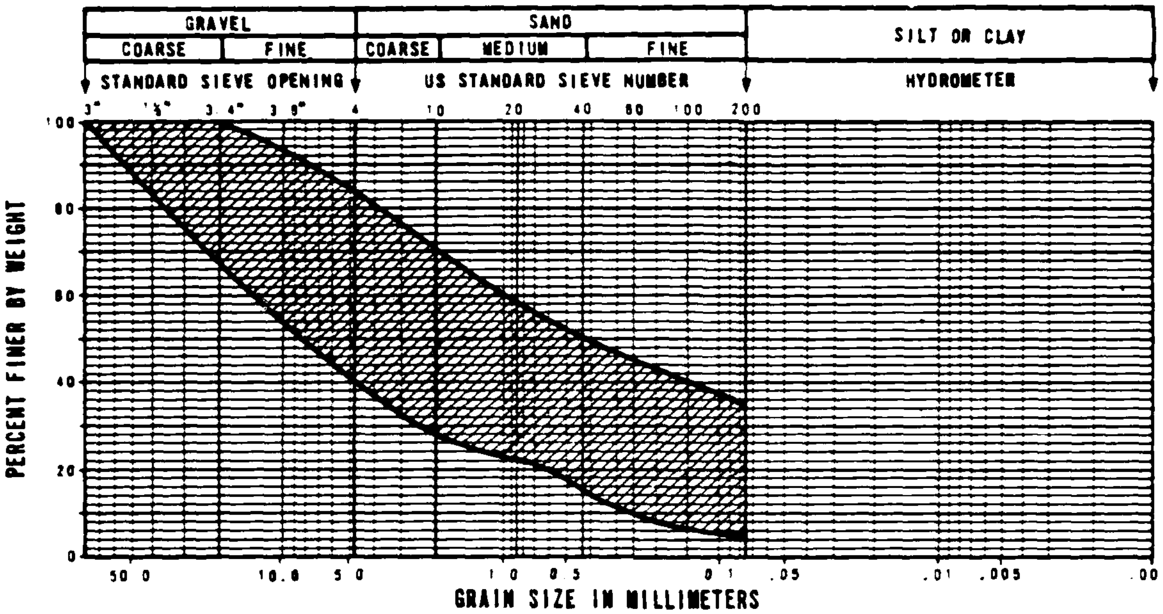
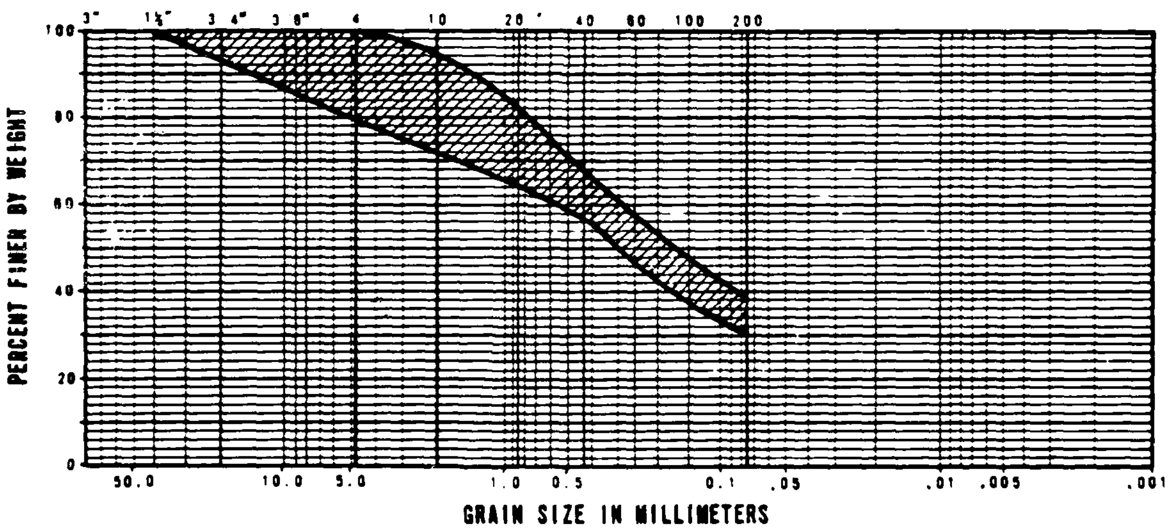
CHARACTERISTICS OF SURFICIAL SOILS
MULESHOE VALLEY, NEVADA

30 JUN 81 TABLE 3-1

2



SOIL DESCRIPTION: Sandy Gravels, Clayey Gravels and Gravelly Sands from 0 to 2 feet (0 to 0.6m)



SOIL DESCRIPTION: Silty Sands and Clayey Sands from 0 to 2 feet (0 to 0.6m)

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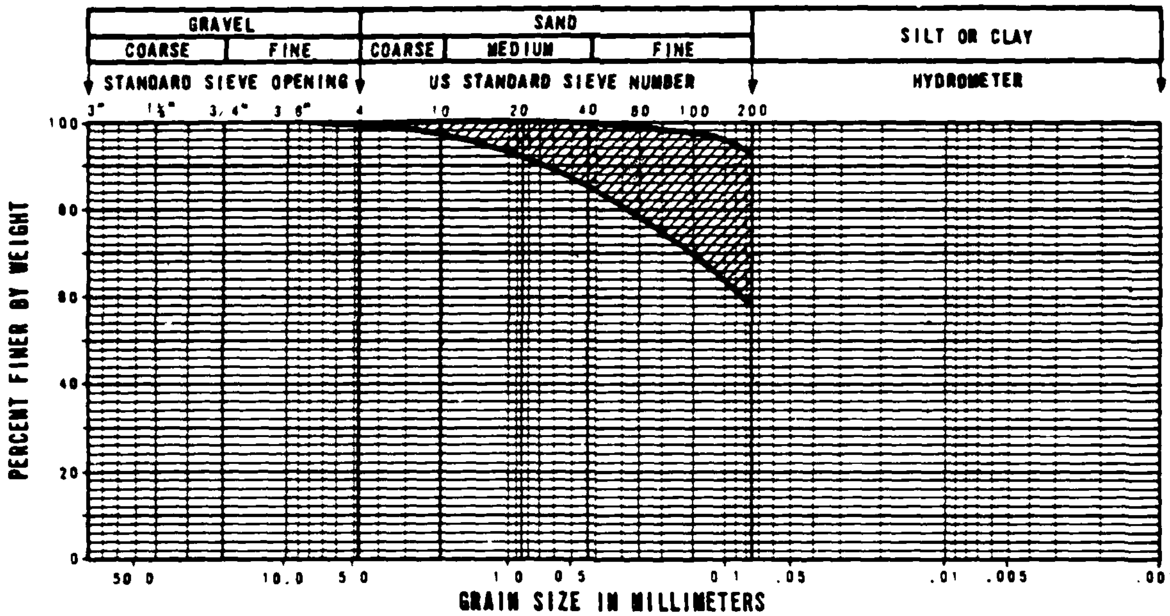
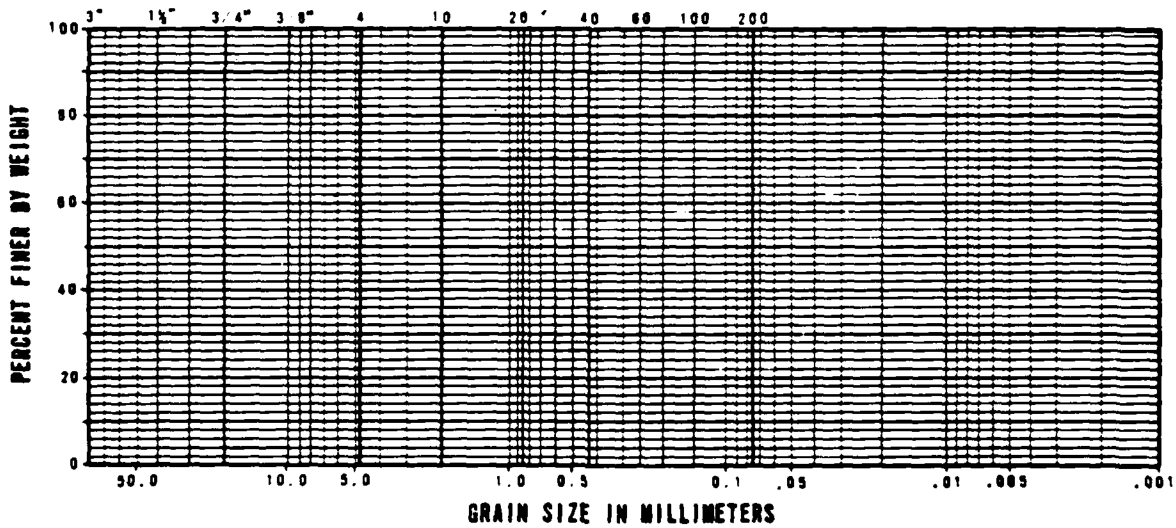
RANGE OF GRADATION OF
SURFICIAL SOILS
MULESHOE VALLEY, NEVADA
PAGE 1 OF 2

30 JUN 81

FIGURE 3-2



SOIL DESCRIPTION: Sandy Silts, Sandy Clays and Silty Clays from 0 to 2 feet (0 to 0.6m)



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RANGE OF GRADATION OF
SURFICIAL SOILS
MULESHOE VALLEY, NEVADA
PAGE 2 OF 2

30 JUN 81 FIGURE 3-2

(0.6 m) have sporadic, weak to strong, calcium-carbonate cementation.

Sandy gravels and gravelly sands cover approximately 10 to 20 percent of the total area. Gravelly soils commonly occur in the intermediate-age fans in the southwest portion of the valley and the old alluvial fans in the central portion of the valley. In general, gravel content increases toward the mountain fronts. Gravelly sands and sandy gravels have a wide range of particle sizes, are occasionally well-graded near the central eastern portion of the valley, and contain trace to some fines. Cobbles and boulders to 12 inches (30 cm) and larger in diameter are encountered sporadically at or near the ground surface in these gravelly deposits.

Silty sands and clayey sands are the predominant surficial soils, covering approximately 75 to 85 percent of the total area. They are widely distributed, being the major component in all areas except in the old alluvial fans near mountain fronts and in the fluvial deposits associated with small stream channels in the northern portion of the valley. The sands are coarse to fine and are poorly graded. They contain some amounts of fines and their plasticity ranges from nonplastic to slightly plastic. The fines content is highest along the central axis and decreases toward the valley margin. Gravel content increases toward the mountain fronts.

Silts and clays cover less than 10 percent of the valley area. They consist of sandy silts, sandy clays, and silty clays. They

occur predominantly along the central axis and the washes in the northern portion of the valley. These soils contain trace to some sand. Their plasticity ranges from nonplastic to slightly plastic.

3.3.2 Low-Strength Surficial Soil

Based on the CPT results and soil classifications, the thickness of low-strength surficial soil at each CPT location was estimated and is presented in Table 3-2.

Summaries of the observed range and mean thickness of the low-strength surficial soil for the three categories are included in Table 3-1. Sandy gravels and gravelly sands exhibit low strength to depths ranging from 0.7 to 1.4 feet (0.2 to 0.4 m), with an average of 1.1 feet (0.3 m). Silty and clayey sands exhibit low strengths to depths ranging from 0.9 to 14.0 feet (0.3 to 4.3 m), with an average of 3.8 feet (1.2 m). The range in the thickness of low-strength granular soils is due to variation in the in-situ density and calcium-carbonate cementation. Silts and clays exhibit low strength to depths ranging from 0.5 to 20.0 feet (0.2 to 6.1 m), with an average of 13.6 feet (4.1 m). The variation in the extent of low-strength, fine-grained soils is due to variations in the in-situ density, the amount of fine sand present, and calcium-carbonate cementation.

3.4 SUBSURFACE SOILS

Coarse-grained (granular) soils are estimated to compose more than 90 percent of the subsurface deposits in the upper 100 feet (30 m). These soils consist of sandy gravels, gravelly sands,

CONE PENETROMETER TEST NUMBER (1)	THICKNESS OF LOW STRENGTH SURFICIAL SOIL, (2)		SOIL TYPE (3)
	FEET	METERS	
C-1	12.2	3.7	CL-ML/SM
C-2	1.0	0.3	SM
C-3	14.6	4.5	CL/SM
C-4	14.0	4.3	SC/SM
C-5	0.7	0.2	GC/GP
C-6	0.5	0.2	CL
C-7	1.1	0.3	SM
C-8	1.3	0.4	SM
C-9	1.3	0.4	SW-SM
C-10	20.0	6.1	ML
C-11	1.2	0.4	GP-GM
C-12	1.4	0.4	GM
C-13	3.1	0.9	SM
C-14	1.2	0.4	SP
C-15	0.9	0.3	SM
C-16	5.6	1.7	SM
C-17	19.7	6.0	ML
C-18	0.9	0.3	SM
C-19	1.1	0.3	GC
C-20	14.5	4.4	ML
C-21	0.8	0.2	GM
C-22	6.7	2.0	SM
C-23	0.9	0.3	SM
C-24	1.1	0.3	SM

CONE PENETROMETER TEST NUMBER (1)	THICKNESS OF LOW STRE SURFICIAL SOIL,(	
	FEET	METER

(1) For Cone Penetrometer Test locations see Drawing 3-1 Activity Location Map.

(2) Thickness corresponds to depth below ground surface. Low strength surficial soil is defined as soil which will perform poorly as a road subgrade at its present consistency. Low strength is based on Cone Penetrometer Test results using the following criteria:

Coarse grained soils: $q_c < 120$ tsf (117 kg/cm^2)
Fine grained soils: $q_c < 80$ tsf (78 kg/cm^2)

where q_c is cone resistance.

(3) Soil type is based on Unified Soil Classification System; see Section A5.0 in the Appendix for explanation

NOTES:
- For fine strength of the s
- SM/GM –
- NDA – No

...NESS OF LOW STRENGTH SURFICIAL SOIL,[2]		SOIL TYPE [3]
...ET	METERS	

CONE PENETROMETER TEST NUMBER[1]	THICKNESS OF LOW STRENGTH SURFICIAL SOIL,[2]		SOIL TYPE [3]
	FEET	METERS	

...ES:
- For fine grained soils (ML, CL, MH and CH), thickness of low strength surficial soil will vary depending on moisture content of the soil at time of testing.
- SM/GM - indicates SM underlain by GM
- NDA - No data available

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THICKNESS OF LOW STRENGTH
SURFICIAL SOILS
MULESHOE VALLEY, NEVADA

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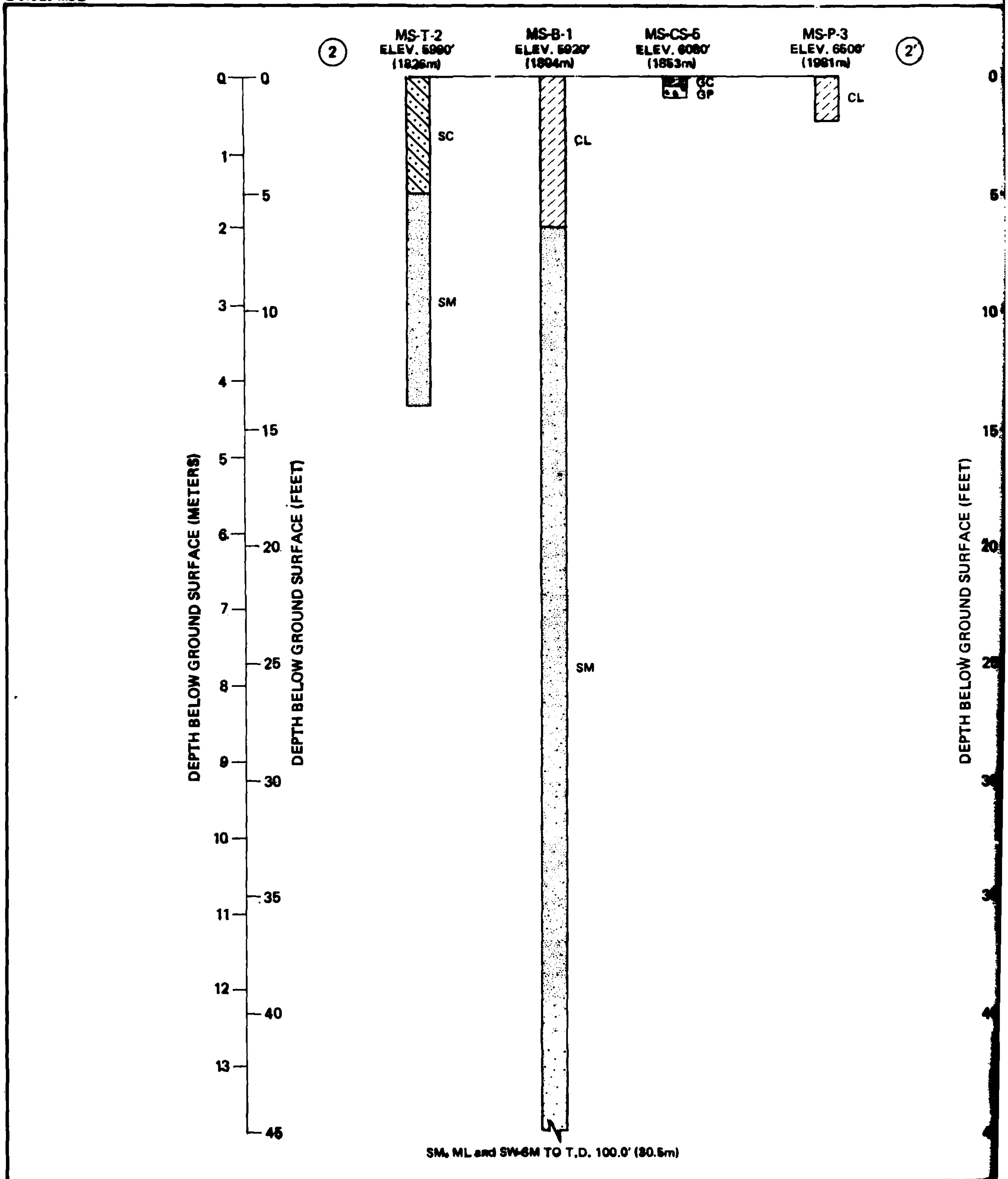
TABLE 3-2

sands, silty sands, and clayey sands. Fine-grained soils are mainly encountered along the central axis and are more noticeable in the northern portion. The fine-grained soils consist of sandy silts, sandy clays, and silty clays with plasticity ranging from nonplastic to slightly plastic. Fine-grained soils are estimated to compose less than 10 percent of the subsurface deposits within the total area boundaries.

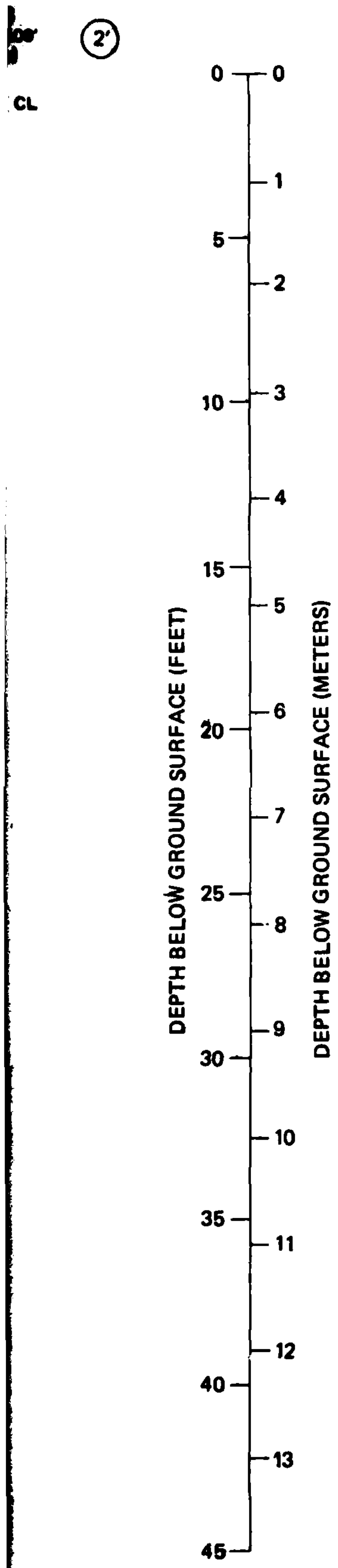
The composition of subsurface soils with depth, as determined from borings, trenches, and test pits, is illustrated in the soil profiles presented in Figures 3-3 through 3-5. Results of seismic and electrical surveys are summarized in Table 3-3. The characteristics of subsurface soils, determined from field and laboratory tests, are presented in Table 3-4. Ranges of gradation of the subsurface soils are shown in Figure 3-6.

Coarse-grained subsurface soils are poorly to well-graded, contain coarse to fine sands and gravels, and are dense to very dense below 3 to 4 feet (0.9 to 1.2 m). Variable cementation occurs intermittently, but well-developed, continuous cementation was not encountered. These soils exhibit low compressibilities and moderate to high shear strengths.

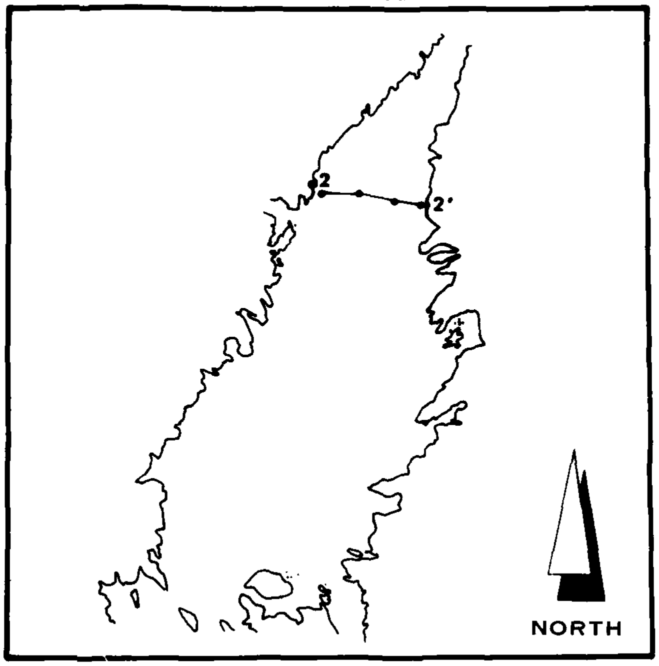
Fine-grained soils (silts and clays) range in consistency from firm to stiff and exhibit low to moderate compressibilities and shear strengths. Soil plasticity ranges from nonplastic to slightly plastic depending in part on the amount of fine sand present. Calcium-carbonate cementation varies from none to moderate, depending primarily on the age of the deposit.



2
MS-T-2
ELEV. 5990'
(1826m)
MS-B-1
ELEV. 5920'
(1804m)
MS-CS-6
ELEV. 6080'
(1853m)
MS-P-3
ELEV. 6500'
(1981m)
2'
SC
SM
CL
SM
GC
GP
CL
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 5 10 15 20 25 30 35 40 45
SM, ML and SW-SM TO T.D. 100.0' (30.5m)



LOCATION MAP



EXPLANATION

B - Boring

T - Trench

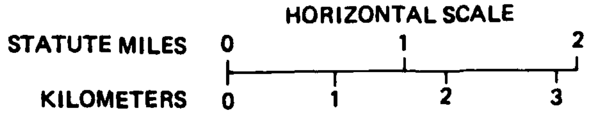
P - Test Pit

CS - Surficial soil sample at Cone Penetrometer Test location.

NOTES:

1. Ground surface elevations shown at activity locations are approximate.
2. T. D. = Total Depth.
3. Soil types shown adjacent to soil column are based on the Unified Soil Classification System (USCS) and are explained in the Appendix.

HORIZONTAL SCALE



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SOIL PROFILE 2–2'
MULESHOE VALLEY, NEVADA

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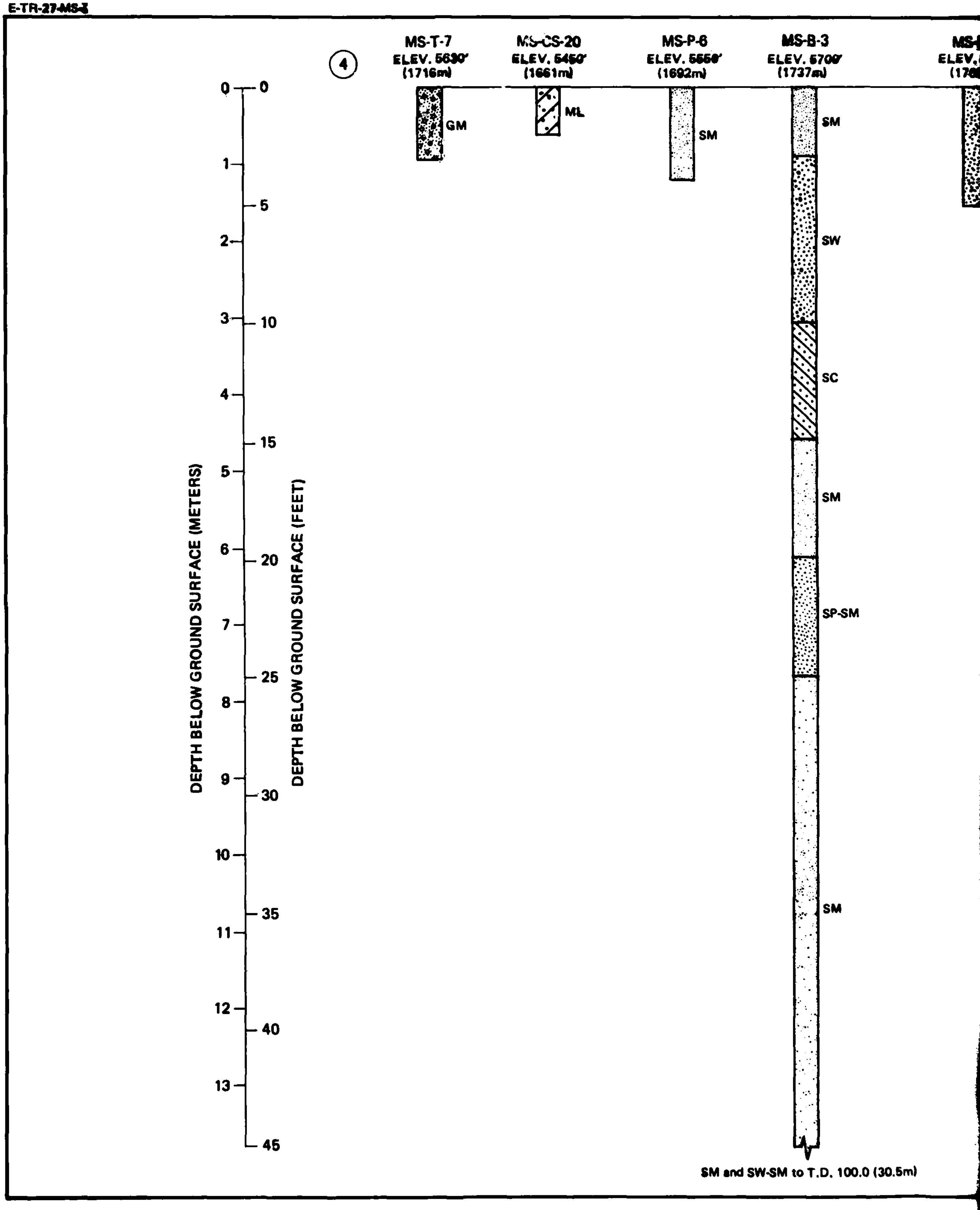
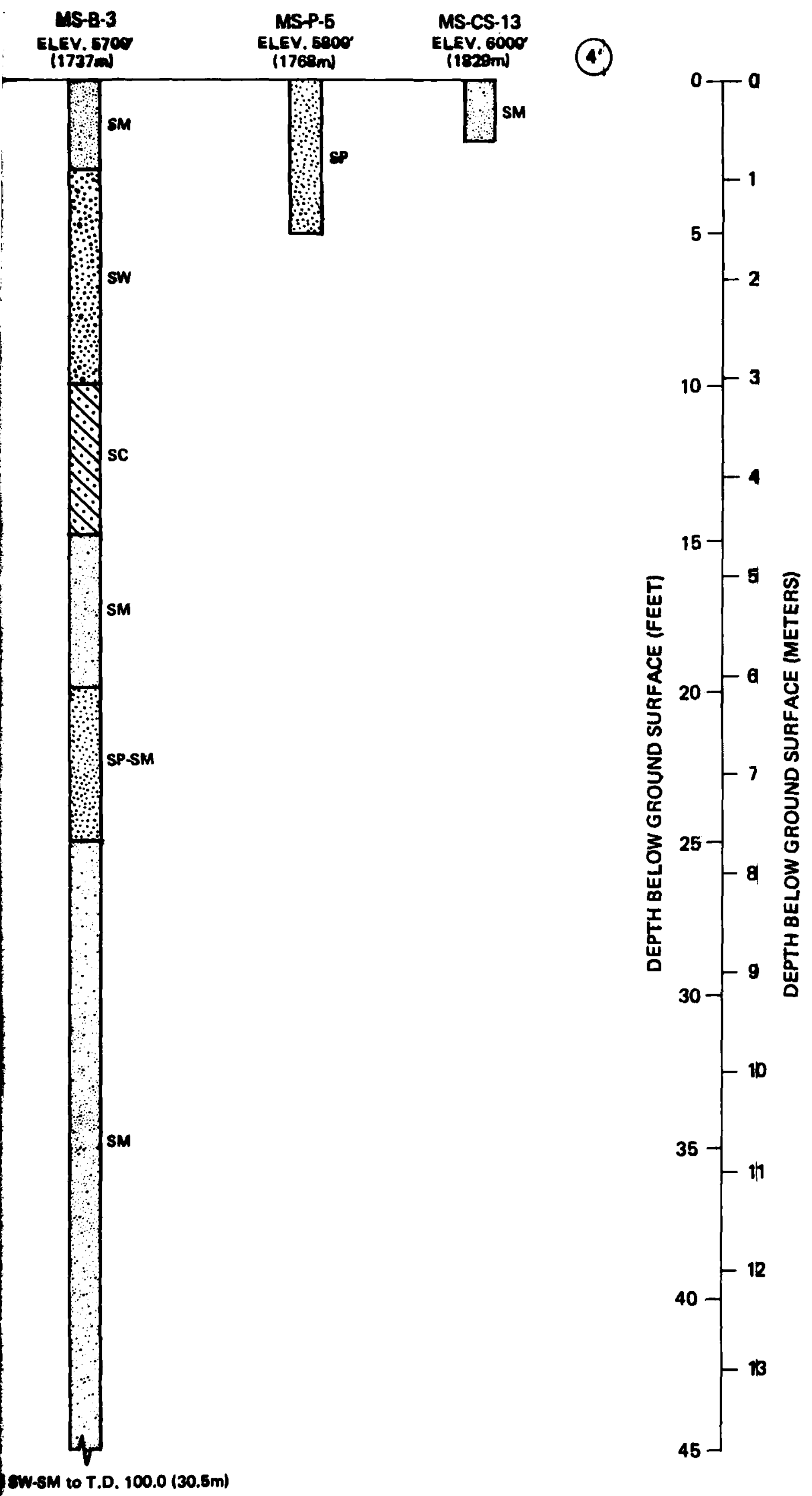
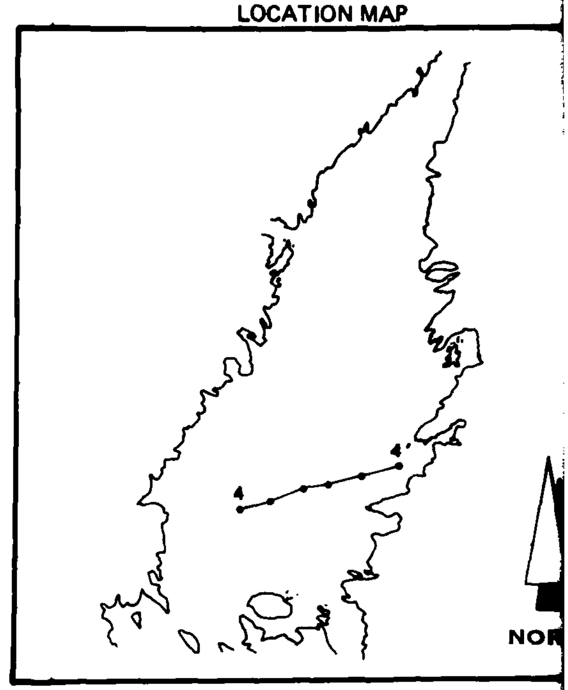
FIGURE 3-3

1 2


4
MS-T-7
ELEV. 5630'
(1716m)
MS-CS-20
ELEV. 5450'
(1661m)
MS-P-6
ELEV. 5550'
(1692m)
MS-B-3
ELEV. 5700'
(1737m)
GM
ML
SM
SM
SW
SC
SM
SP-SM
SM
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
SM and SW-SM to T.D. 100.0 (30.5m)



LOCATION MAP



EXPLANATION

B - Boring

T - Trench

P - Test Pit

CS - Surficial soil sample at Cone Penetrometer Test location.

NOTES:

1. Ground surface elevations shown at activity locations are app
2. T. D. = Total Depth.
3. Soil types shown adjacent to soil column are based on the U Classification System (USCS) and are explained in the Appe

HORIZONTAL SCALE

STATUTE MILES 0 1 2

KILOMETERS 0 1 2 3

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MX SIT
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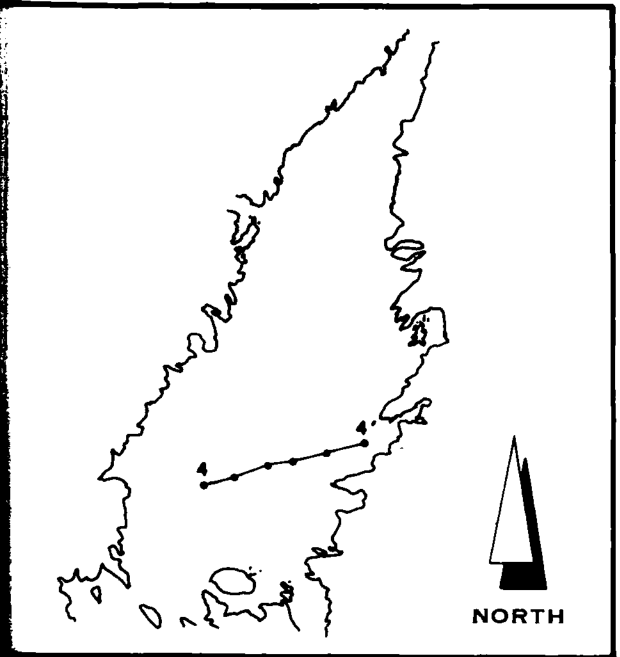
SOIL PROFIL
MULESHOE VALLE

30 JUN 81

LOCATION MAP



EXPLANATION

ing

nch

t Pit

rficial soil sample at Cone Penetrometer Test location.

und surface elevations shown at activity locations are approximate.
D. = Total Depth.
types shown adjacent to soil column are based on the Unified Soil
sification System (USCS) and are explained in the Appendix.

HORIZONTAL SCALE

E MILES 0 1 2

METERS 0 1 2 3

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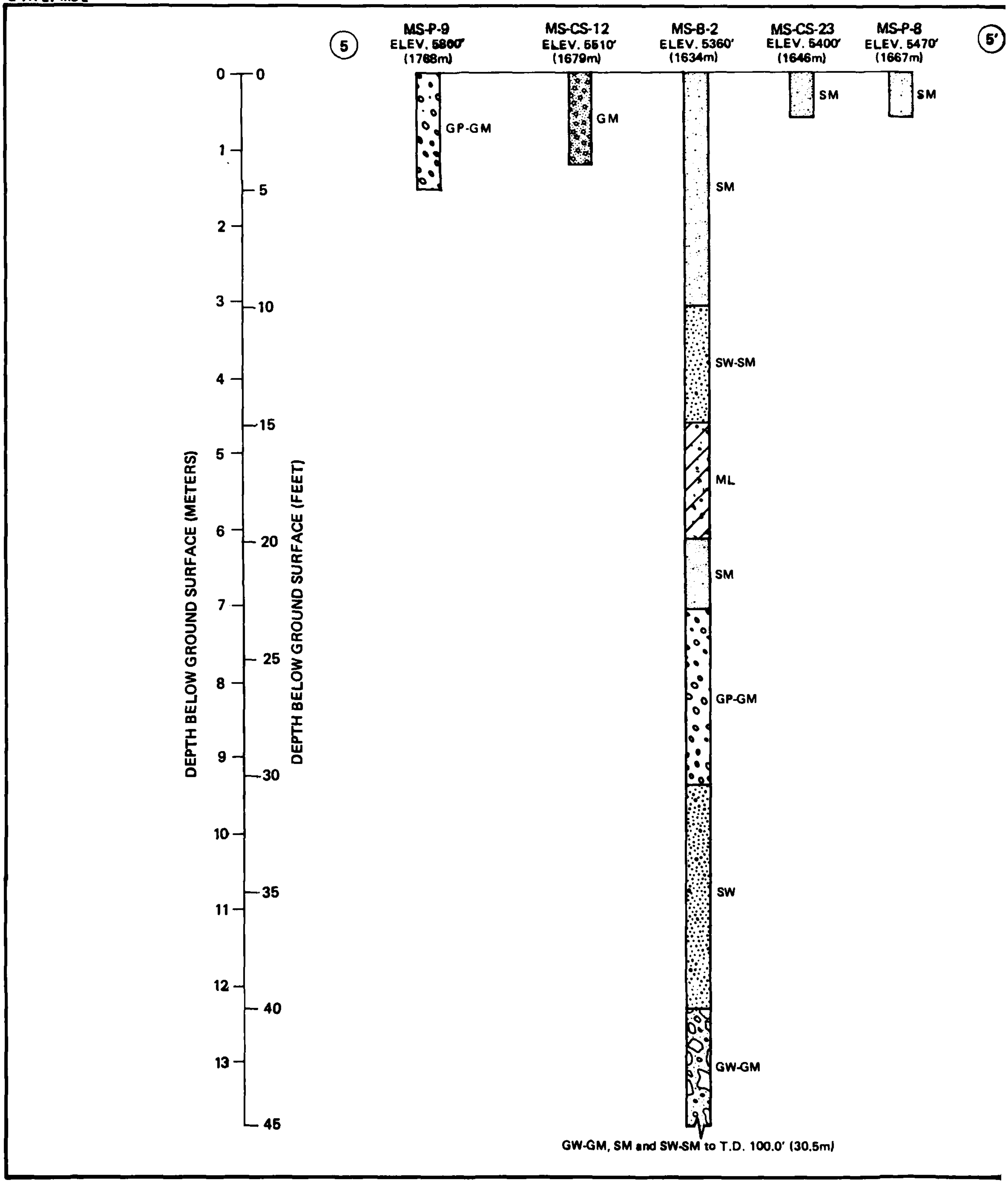
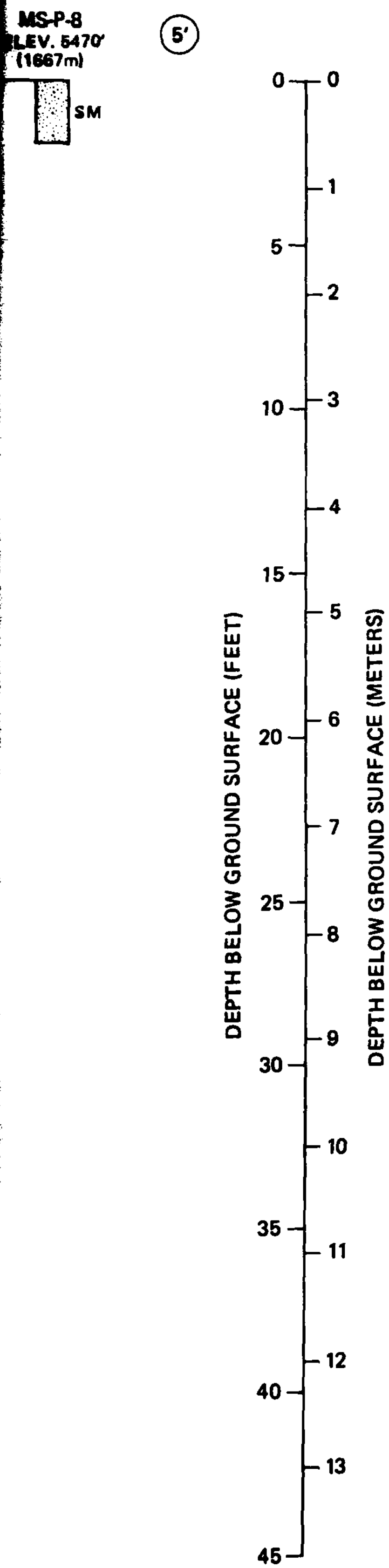
SOIL PROFILE 4–4'
MULESHOE VALLEY, NEVADA

30 JUN 81

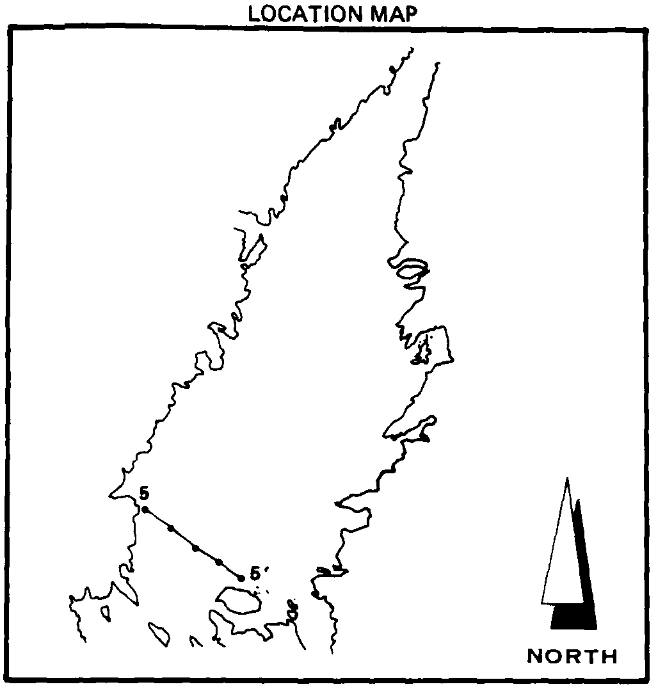
FIGURE 3-4

13


5
MS-P-9
ELEV. 5800'
(1768m)
MS-CS-12
ELEV. 5510'
(1679m)
MS-B-2
ELEV. 5360'
(1634m)
MS-CS-23
ELEV. 5400'
(1646m)
MS-P-8
ELEV. 5470'
(1667m)
5'
GP-GM
GM
SM
SM
SM
SW-SM
ML
SM
GP-GM
SW
GW-GM
DEPTH BELOW GROUND SURFACE (METERS)
DEPTH BELOW GROUND SURFACE (FEET)
0 1 2 3 4 5 6 7 8 9 10 11 12 13
0 5 10 15 20 25 30 35 40 45
GW-GM, SM and SW-SM to T.D. 100.0' (30.5m)



LOCATION MAP



EXPLANATION

B - Boring

T - Trench

P - Test Pit

CS - Surficial soil sample at Cone Penetrometer Test location.

NOTES:

1. Ground surface elevations shown at activity locations are approximate.
2. T. D. = Total Depth.
3. Soil types shown adjacent to soil column are based on the Unified Soil Classification System (USCS) and are explained in the Appendix.

HORIZONTAL SCALE

STATUTE MILES 0 1 2

KILOMETERS 0 1 2 3

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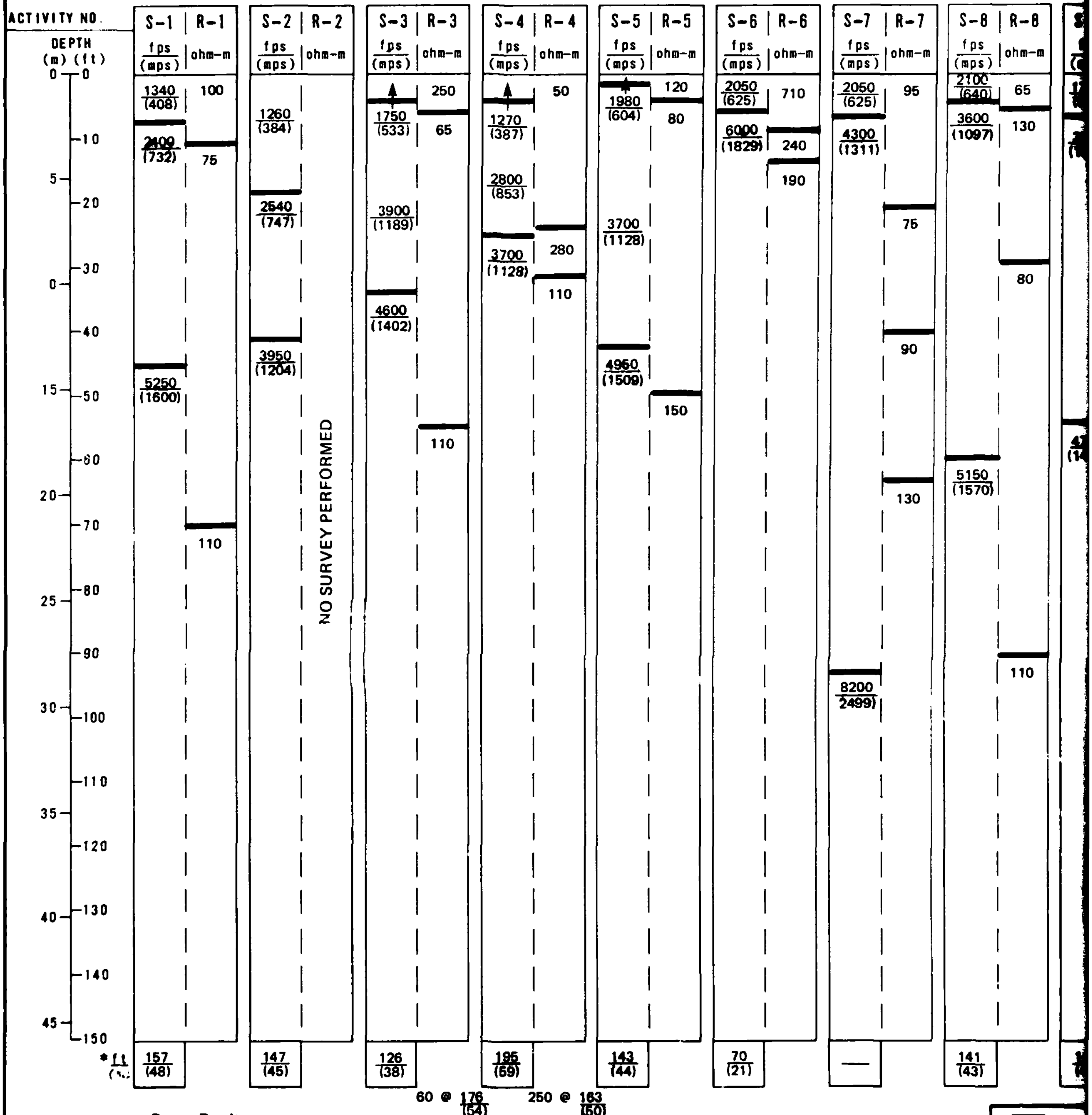
SOIL PROFILE 5–5'
MULESHOE VALLEY, NEVADA

30 JUN 81

FIGURE 3-8



Deeper Results
Velocity/Resistivity @ Depth

* Approximate depth above which there is no indication of material with a velocity as great as 7000 fps (2134 mps). See Appendix A for an explanation of how this exclusion depth is calculated when the observed velocities are all less than 7000 fps (2134 mps).

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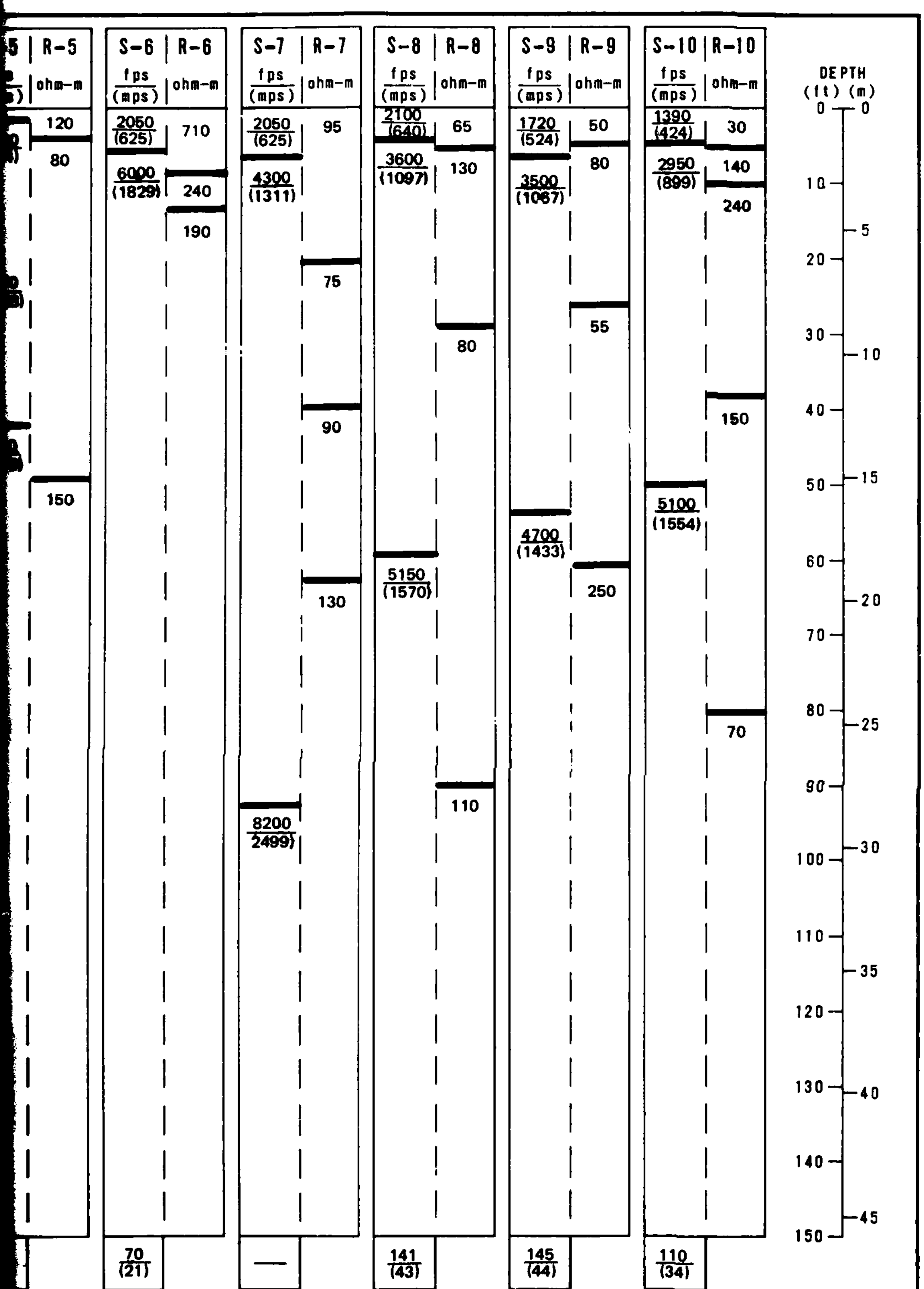

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SEISMIC REFRACTION AND
ELECTRICAL RESISTIVITY RESULTS
MULESHOE VALLEY, NEVADA

30 JUN 81

TABLE 3-3

AFV-18

2

DEPTH RANGE	2' - 20' (0.6 - 6.0m)		
SOIL DESCRIPTION	Coarse-grained soils		Fine-grained s
	Gravelly Sands, Sands, Silty Sands and Clayey Sands		Sandy Silts, Sandy Clay and Silty Clays
USCS SYMBOLS	SW, SM, SC		ML, CL
ESTIMATED EXTENT IN SUBSURFACE %	90 - 95		5 - 10
PHYSICAL PROPERTIES			
DRY DENSITY pcf (kg/m³)	90.7 - 117.8 (1453 - 1887)	[11]	72.6 - 96.1 (1163 - 1540)
MOISTURE CONTENT %	4.2 - 13.6	[11]	6.8 - 11.4
DEGREE OF CEMENTATION	none to strong		none to moderate
COBBLES 3 - 12 inches (8 - 30 cm) %	0 - 15*		0 - 5*
GRAVEL %	1 - 45	[8]	0 - 1
SAND %	49 - 93	[8]	7 - 41
SILT AND CLAY %	3 - 36	[8]	58 - 93
LIQUID LIMIT	31	[1]	31 - 33
PLASTICITY INDEX	NP - 13	[6]	NP - 15
COMPRESSIONAL WAVE VELOCITY fps (mps)	1260 - 6000 (384 - 1829)	[19]	1260 - 2400 (384 - 732)
SHEAR STRENGTH DATA			
UNCONFINED COMPRESSION S_u - ksf (kN/m²)	NDA		1.3 (62)
TRIAXIAL COMPRESSION c - ksf (kN/m²), ø°	NDA		NDA
DIRECT SHEAR c - ksf (kN/m²), ø°	c = 0.6 (29) ø = 38	[1]	NDA

NOTES:

- Characteristics of soils between 2 and 20 feet (0.6 and 6.0 meters) are based on results of tests on samples from 3 borings, 3 trenches, and results of 10 seismic refraction surveys.
- Characteristics of soils below 20 feet (6.0 meters) are based on results of tests on samples from 3 borings and results of 10 seismic refraction surveys.

- [ ] - Number
- NDA - No data
- * - Estimate

6.0m)	20' - 160' (6.0 - 49.0m)	
Fine-grained soils	Coarse-grained soils	Fine-grained soils
ndy Silts, Sandy Clays d Silty Clays	Sandy Gravels, Gravelly Sands, Sands and Silty Sands	Sandy Silts
L, CL	GW, GP, SW, SP, SM	ML
- 10	90 - 95	5 - 10
72.6 - 96.1 163 - 1540) [4]	88.4 - 121.1 (1416 - 1940) [33]	96.7 (1549) [1]
8 - 11.4 [4]	4.2 - 26.9 [33]	19.3 [1]
ne to moderate	none to strong	none
- 5*	0 - 5*	0
- 1 [4]	0 - 67 [21]	0 [1]
- 41 [4]	28 - 90 [21]	49 [1]
- 93 [4]	3 - 40 [21]	51 [1]
- 33 [2]	22 [1]	NDA
P - 15 [4]	NP - 3 [6]	NP [1]
80 - 2400 84 - 732) [4]	2400 - 6000 (732 - 1829) [19]	NDA
3 2) [1]	1.0 (48) [1]	NDA
DA	c = 0.0 - 1.5 (0 - 72) ø = 38 - 39 [2]	NDA
DA	c = 0.5 (24) ø = 46 [1]	NDA

- [ ] - Number of tests performed.
- NDA - No data available (insufficient data or tests not performed.)
- * - Estimate

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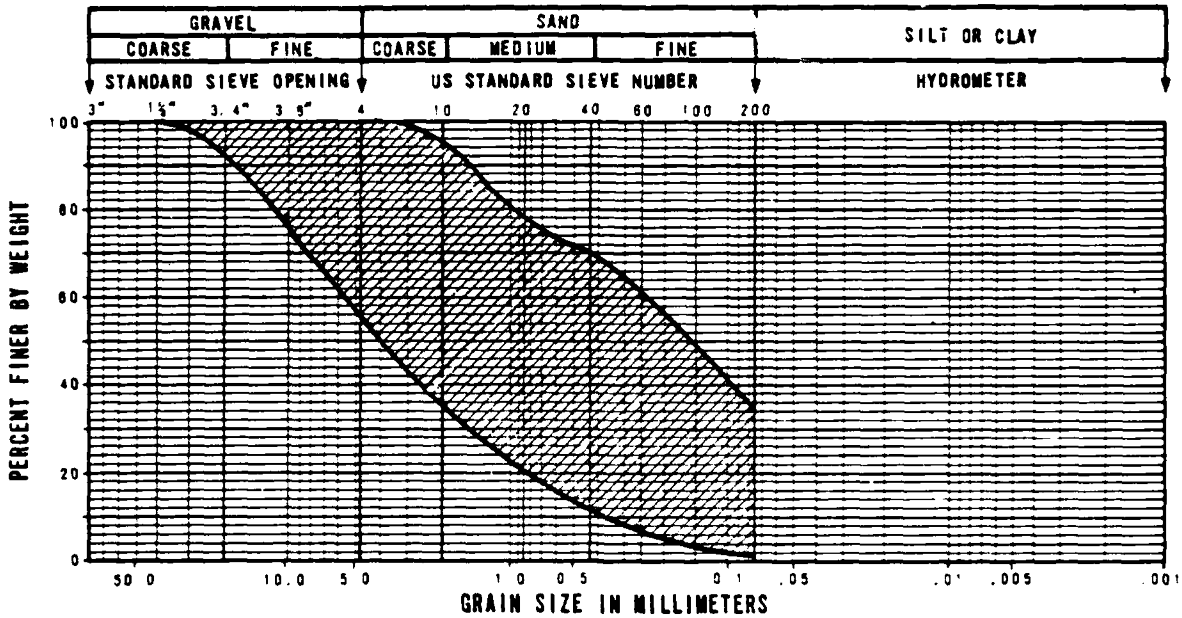
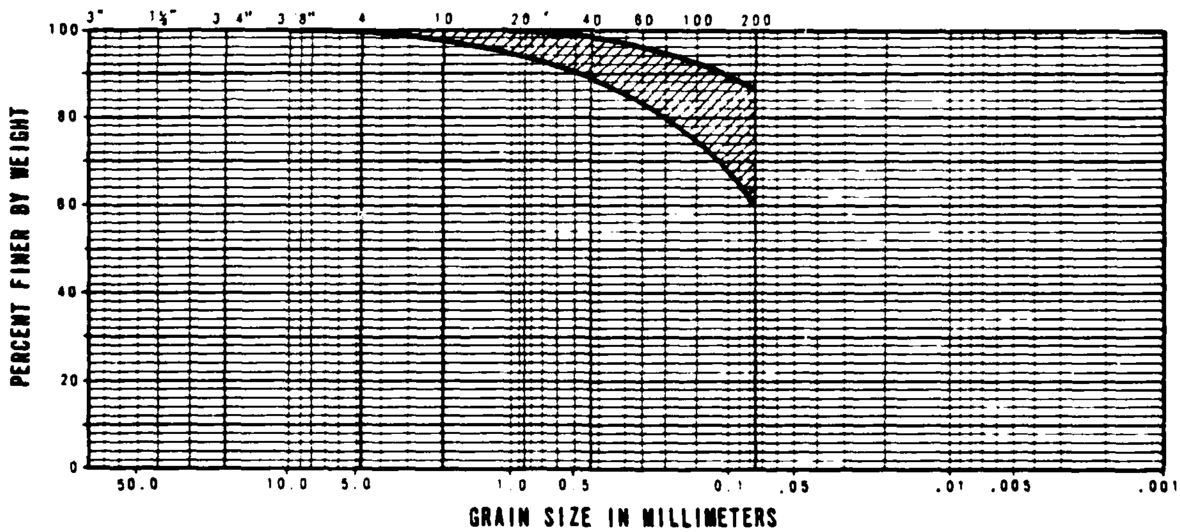
CHARACTERISTICS OF SUBSURFACE SOILS
MULESHOE VALLEY, NEVADA

TABLE 3-4

12



SOIL DESCRIPTION: Coarse-Grained Soils
from 2 to 20 feet (0.6 to 6.0m)



SOIL DESCRIPTION: Fine-Grained Soils
from 2 to 20 feet (0.6 to 6.0m)

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RANGE OF GRADATION OF
SUBSURFACE SOILS
MULESHOE VALLEY, NEVADA
PAGE 1 OF 2

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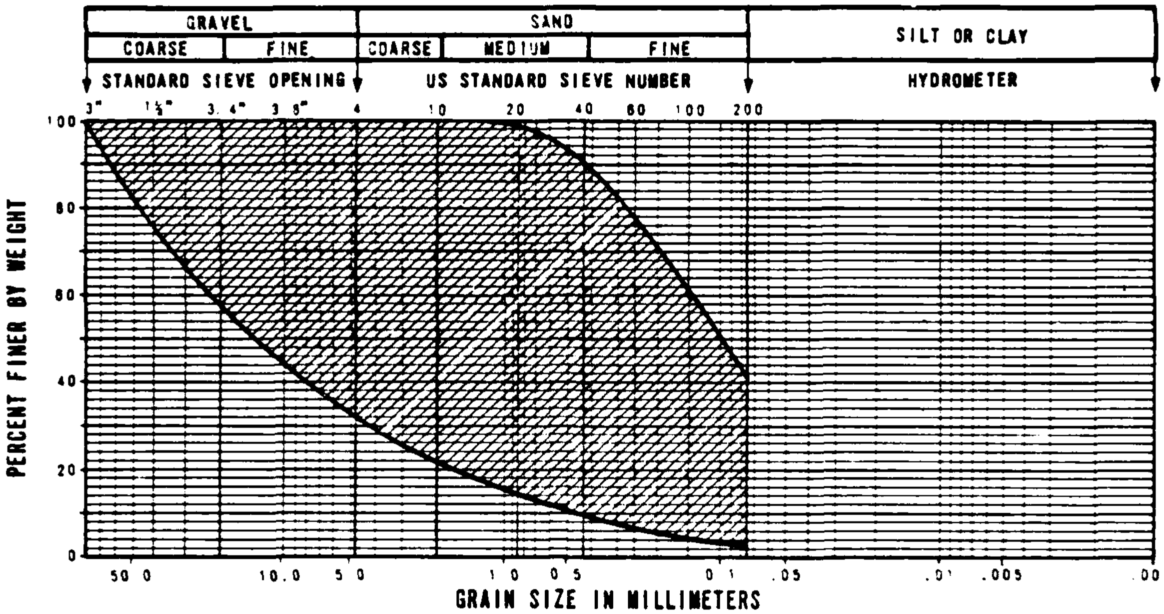
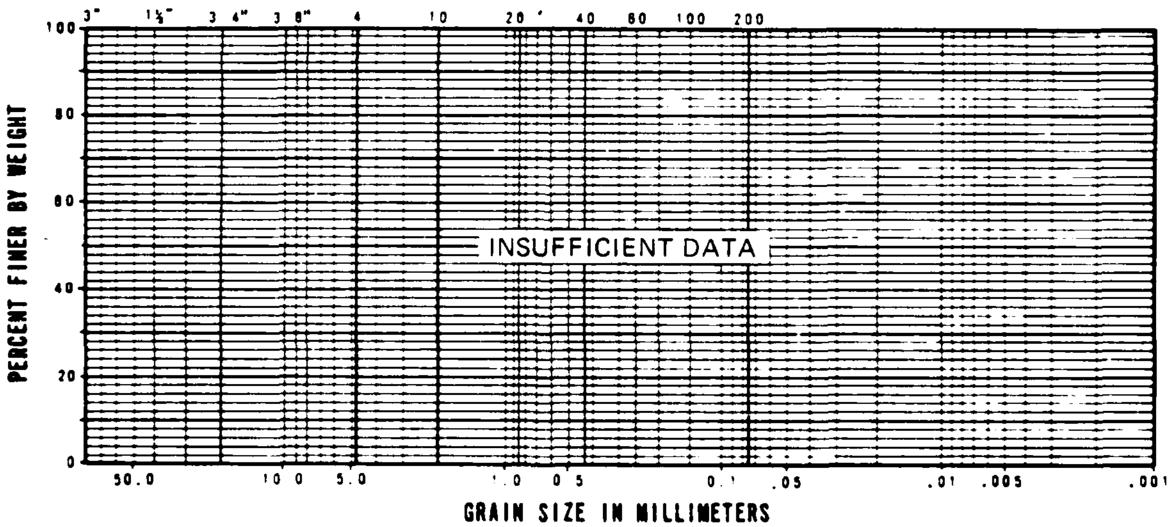
FIGURE 3-6



SOIL DESCRIPTION: Coarse-Grained Soils
from 20 to 2 160 feet (6.0 to 49.0m)



SOIL DESCRIPTION: Fine-Grained Soils
from 20 to 160 feet (6.0 to 49.0m)

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RANGE OF GRADATION OF
SUBSURFACE SOILS
MULESHOE VALLEY, NEVADA
PAGE 2 OF 2

30 JUN 81

FIGURE 3-6

The soils in the construction zone (120 feet [37 m]) have a wide range of seismic compressional wave velocities (1260 to 6000 fps [384 to 1829 mps]) depending on their composition, consistency, cementation, and moisture content. Seismic compressional wave velocities were measured in only the coarse-grained soils. Generally, velocities in fine-grained soils are found to be substantially lower than those in coarse-grained soils. Compressional wave velocities for deeper materials are also listed in Table 3-3.

Electrical conductivity measured for the soils in the upper 50 feet (15 m) ranged from 0.0034 to 0.0154 mhos per meter (average 0.0101 mhos per meter). At one of the nine measurement locations, the measured conductivities were less than the minimum value of 0.004 mhos per meter specified in the *Fine Screening* criteria.

Results of chemical tests done on five samples from Muleshoe Valley indicate that potential for sulfate attack for soils on concrete will be "negligible."

3.5 DEPTH TO ROCK

Drawing 3-3 shows the 50- and 150-foot (15- and 46-m) depth-to-rock contours in Muleshoe Valley. This interpretation is based on limited point data from borings, seismic refraction surveys, site-specific published data, and depths inferred from geologic and geomorphic relationships. Approximately 21 percent of the basin-fill material in the valley is interpreted to be underlain by rock at depths of less than 50 feet (15 m). An additional

three percent of the valley is interpreted to be underlain by shallow rock between depths of 50 and 150 feet (15 and 46 m).

The bedrock-fill contact on the western side of the valley is highly irregular with numerous small re-entrant canyons. An area in the northwestern portion of the valley extending from the Schell Creek Range has been interpretated to be underlain by shallow rock. Numerous outcrops of sedimentary and volcanic rocks protrude through the overlying intermediate-age alluvium up to 1 1/2 miles (2.4 km) from the mountain front. Based on these outcrops, the area where rock is interpreted to be at depths of less than 50 feet (15 m) forms a strip varying from one-eighth mile (0.2 km) to 2 miles (3.2 km) in width along the entire western margin of the valley. An outcrop of rock in the south central portion of the valley approximately one-half mile (.8 km) from the mountain front is interpreted to be surrounded by a narrow belt of shallow rock.

The eastern side of the valley is characterized by a moderately to highly irregular mountain front interrupted by long re-entrant canyons. These re-entrant canyons contain alluvial fan or fluvial sediments interpreted to be thin veneers overlying bedrock.

3.6 DEPTH TO WATER

The only source of ground-water data in Muleshoe Valley is a well recorded by the State of Nevada Engineer's Office (Drawing 3-4). The boring was dry to its total depth of about 290 feet (88 m). No ground-water contours are shown in Drawing 3-4

since there are no data to establish the presence of ground water in Muleshoe Valley.

3.7 TERRAIN

3.7.1 Terrain Exclusions

Terrain conditions are shown in Drawing 3-5. Areas designated as terrain exclusions are considered to be unsuitable based on a combination of field-derived and office-derived data which were evaluated under the criteria in Appendix Table A2-1. Field derived exclusions include: 1) areas having very steep slopes, such as the sides of major drainages; and 2) areas in which incisions deeper than 10 feet (3 m) are spaced closer than 1000 feet (305 m) apart. Office-derived exclusions consist primarily of identifying areas on topographic maps that have slopes greater than 10 percent. In some instances, where road access is inadequate for field inspection, office analysis of aerial photographs was used to define and exclude areas of rugged or adverse terrain. However, preference was given to determining such exclusions in the field. Even though areas where slopes exceed five percent are considered to be suitable for deployment, they are shown in Drawing 3-5 because they require special consideration in planning construction and operations.

Several portions of Muleshoe Valley are excluded based on the terrain criteria. Areas of terrain exclusions on the eastern side of the valley border deeply-incised major tributaries. In the central part of the valley, the axial drainage (Coyote Wash) is partially bordered by similar exclusions. Most of these

terrain exclusion areas are based on the incision depth-spacing criteria (field determined). Some areas in the northeasternmost and southwesternmost portions of the valley are excluded based upon the 10 percent slope exclusion criteria.

3.7.2 Incision Depths and Number of Drainages Per Mile

Data on incision depths and number of drainages encountered per mile were analyzed for Muleshoe Valley. Information on incision depths was obtained from field observations; the number of drainages per mile was determined from both field observations and interpretation of aerial photographs.

The results shown in Table 3-5 are average values of the two drainage characteristics (depth and number per mile). They are listed for each prevalent surficial unit with further breakdowns providing data on 1) characteristics in the unit on each side of the valley axial drainage and 2) characteristics of the unit where its surface slopes are between five and 10 percent versus areas where its slopes are less than five percent.

The small areal extent of some of the surficial units resulted in limited or insufficient data for analysis (Table 3-5). The available data show the intermediate-age fan unit (A5i) has the greatest number of drainages per mile and the deepest incision depths. Drainages are typically deeper in this unit on the eastern side of the valley than on the western side, but are more numerous on the western side. Incision depths vary within the different geomorphic units depending upon grain size of the unit and the degree of surface slope.

SURFICIAL GEOLOGIC UNIT	AVERAGE NUMBER OF DRAINAGES PER MILE			
	WESTERN SIDE OF VALLEY		EASTERN SIDE OF VALLEY	
	SURFACE SLOPE, %		SURFACE SLOPE, %	
	0 - 5	5 - 10	0 - 5	5 - 10
A5os	—	4.0 •	—	—
A5ig	—	—	—	—
A5is	10.2 (3.8)	13.0 •	6.8 (2.4)	—

NOTE: DRAINAGES WERE COUNTED ALONG A ONE-MILE LINE PERPENDICULAR TO THE DRAINAGE DIRECTION

SURFICIAL GEOLOGIC UNIT	AVERAGE DEPTH OF INCISIONS			
	WESTERN SIDE OF VALLEY		EASTERN SIDE OF VALLEY	
	SURFACE SLOPE, %		SURFACE SLOPE, %	
	0 - 5	5 - 10	0 - 5	5 - 10
A5os	—	7.5 ft • 2.3 m	8.5 ft (5.4 ft) 2.6 m (1.6 m)	—
A5ig	5.3 ft (1.7 ft) 1.6 m (.5m)	—	—	—
A5is	6.4 ft (2.9 ft) 2.0 m (.9 m)	8.1 ft (5.7 ft) 2.5 m (1.7 m)	8.8 ft (5.8 ft) 2.7 m (1.8 m)	10.4 ft (4.9 m) 3.2 m (1.5 m)

•	LIMITED DATA (6 < n < 10) VALUE IS MEDIAN, NO STANDARD DEVIATION
—	NO DATA OR INSUFFICENT DATA (n < 6)
( )	STANDARD DEVIATION
A5o	OLD-AGE ALLUVIAL FANS
A5i	INTERMEDIATE-AGE ALLUVIAL FANS
g	GRAVELS
s	SANDS
f	FINES; CLAYS, SILTS

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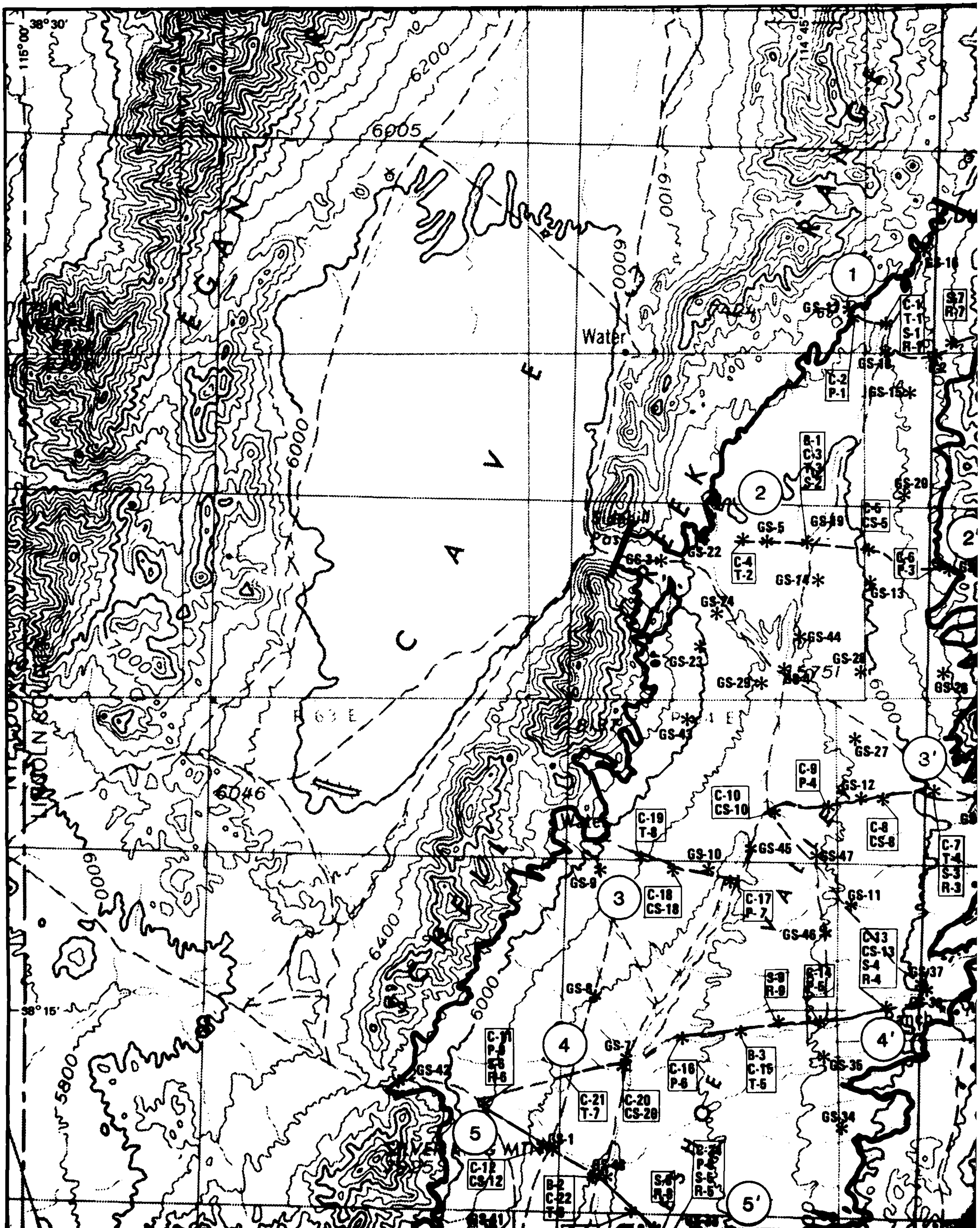
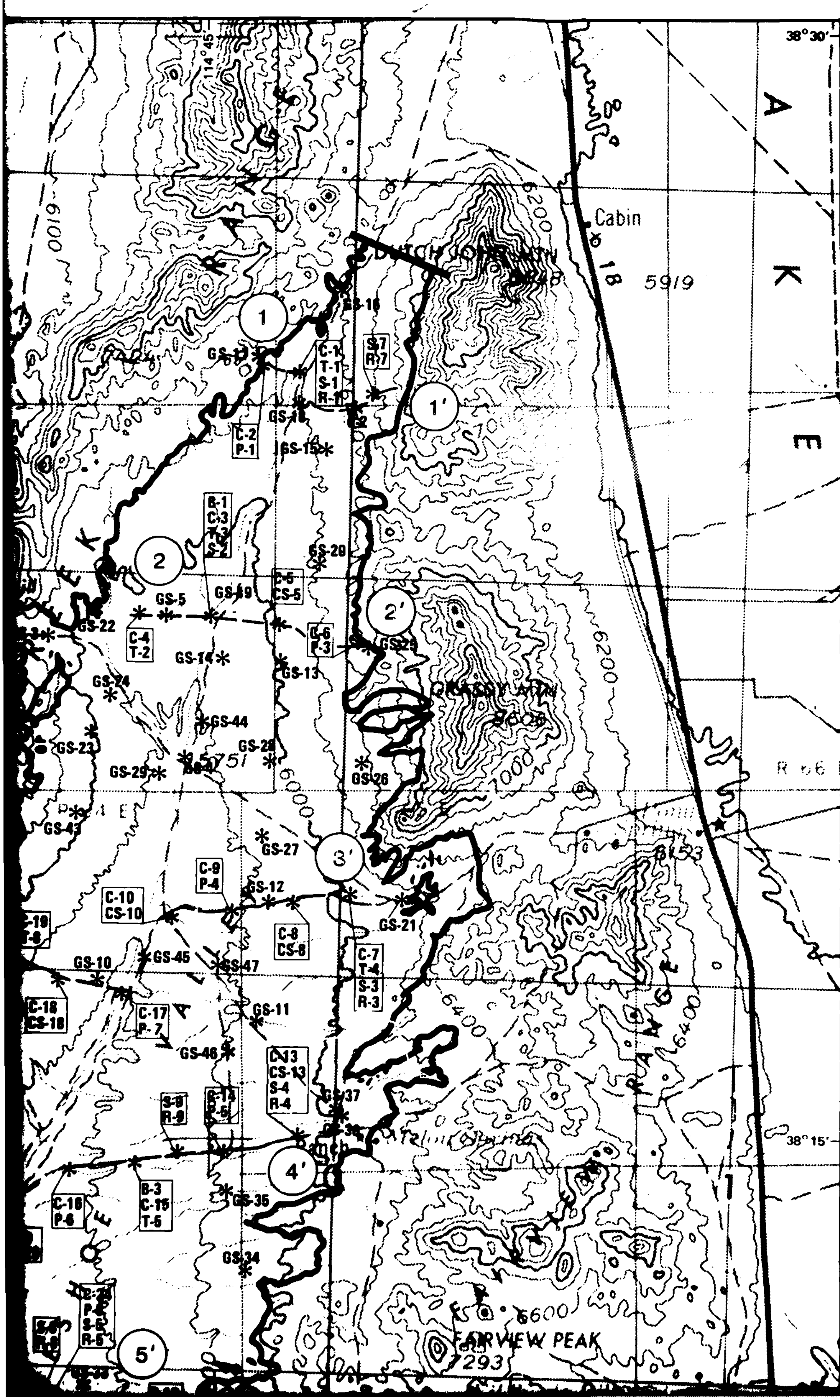
DRAINAGES PER MILE AND DEPTH OF INCISIONS IN PREVALENT SURFICIAL GEOLOGIC UNITS MULESHOE VALLEY, NEVADA

30 JUN 81 TABLE 3-5

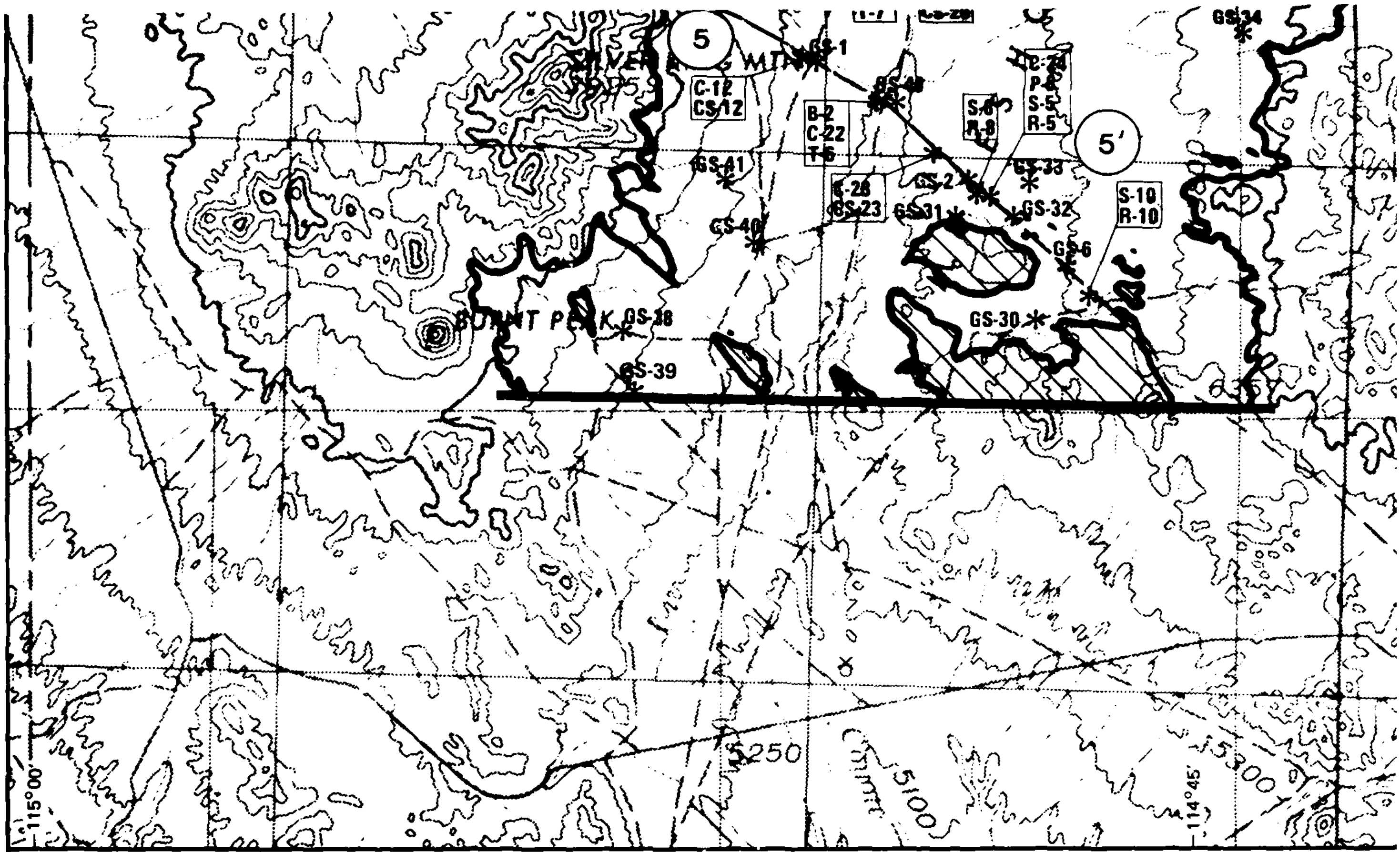


38°30'
115°00'
114°45'
38°15'
7000
6200
6005
6100
6000
6046
6400
5800
5751
Water
1
2
2'
3
3'
4
4'
5
5'
C-1
T-1
S-1
R-1
S-7
R-7
C-2
P-1
GS-15
GS-16
B-1
C-3
C-5
CS-5
C-4
T-2
C-6
P-3
GS-5
GS-19
GS-22
GS-3
GS-14
GS-13
GS-24
GS-44
GS-23
GS-20
GS-29
GS-27
GS-12
GS-43
GS-26
GS-28
C-9
P-4
C-10
CS-10
C-8
CS-8
C-19
T-8
GS-10
GS-45
GS-47
C-7
T-4
S-3
R-3
GS-9
C-18
CS-18
C-17
P-7
GS-11
GS-46
C-13
CS-13
S-4
R-4
GS-37
S-9
R-9
GS-8
GS-7
B-3
C-15
T-5
C-16
P-6
GS-35
GS-42
C-21
T-7
C-20
CS-20
GS-34
GS-1
C-12
CS-12
B-2
C-22
GS-41



38° 30'
Cabin
18
5919
A
K
E
1
1'
2
2'
3'
4'
5'
GS-16
C-1
T-1
S-1
R-1
S-7
R-7
GS-18
C-2
P-1
GS-15
B-1
C-3
T-3
S-2
GS-20
GS-5
GS-22
C-4
T-2
C-5
CS-5
C-6
P-3
GS-14
GS-13
GS-24
GS-44
GS-23
GS-29
GS-26
GS-43
GS-27
C-9
P-4
GS-12
C-10
CS-10
C-8
CS-8
GS-21
C-7
T-4
S-3
R-3
GS-10
GS-45
GS-47
C-18
CS-18
C-17
P-7
GS-11
GS-46
C-13
CS-13
S-4
R-4
GS-37
S-8
R-9
38° 15'
B-3
C-15
T-5
C-16
P-6
GS-35
GS-34
5'
6200
6000
7000
6400
6600
8153
R 56
GRASSY MTN
FAIRVIEW PEAK
7293

E-TR-27-MS-I



EXPLANATION

*	ACTIVITY LOCATION
GS-1	GEOLOGIC STATION
B-1	BORING
C-1	CONE PENETROMETER TEST (CPT)
CS-1	SURFICIAL SOIL SAMPLE
T-1	TRENCH
P-1	TEST PIT
S-1	SEISMIC REFRACTION LINE
R-1	ELECTRICAL RESISTIVITY SOUNDING
1 — — 1′	ACTIVITY LINE
	Contact between rock and basin-fill.
	Valley borders.

30 JUN 81

ACTIVIT

MULESHOE

AD-A112 999 ERTEC WESTERN INC LONG BEACH CA F/G 13/2
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UNCLASSIFIED E-TR-27-MS-1 NL

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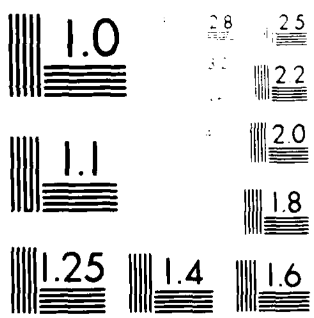

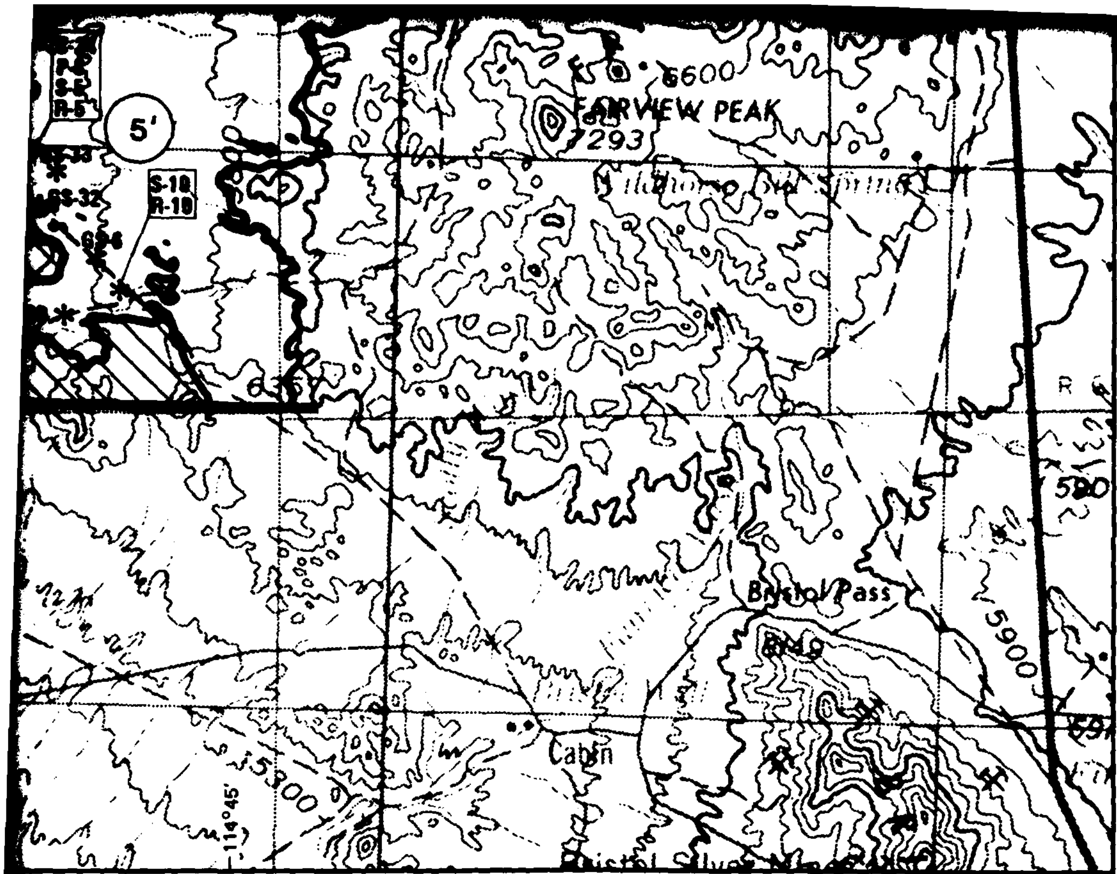

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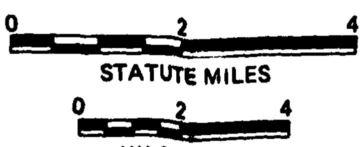

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EXPLANATION

*	ACTIVITY LOCATION
GS-1	GEOLOGIC STATION
B-1	BORING
C-1	CONE PENETROMETER TEST (CPT)
CS-1	SURFICIAL SOIL SAMPLE
T-1	TRENCH
P-1	TEST PIT
S-1	SEISMIC REFRACTION LINE
R-1	ELECTRICAL RESISTIVITY SOUNDING
1 — — 1'	ACTIVITY LINE
	Contact between rock and basin-fill.
	Valley borders.
	Areas of isolated exposed rock.

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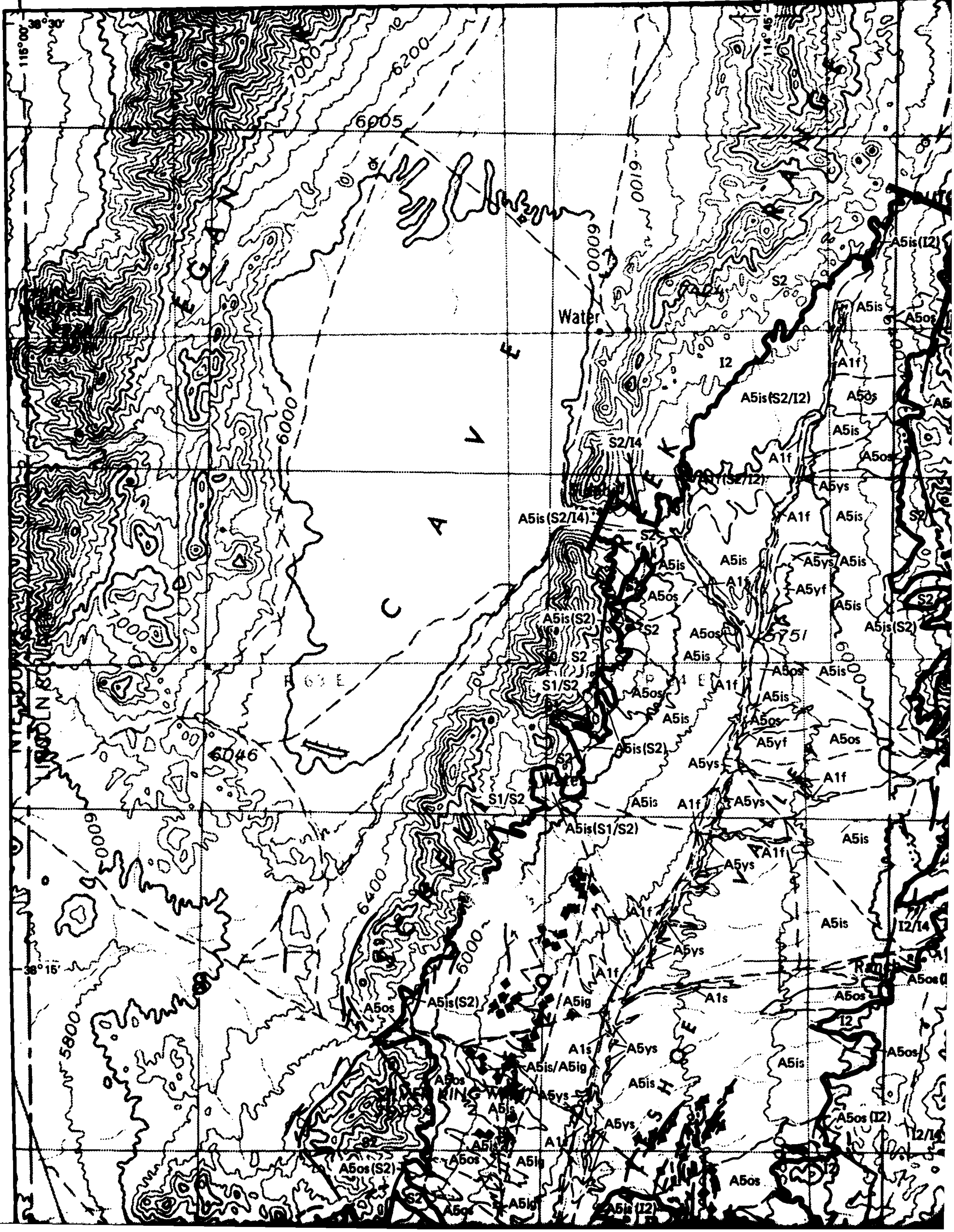
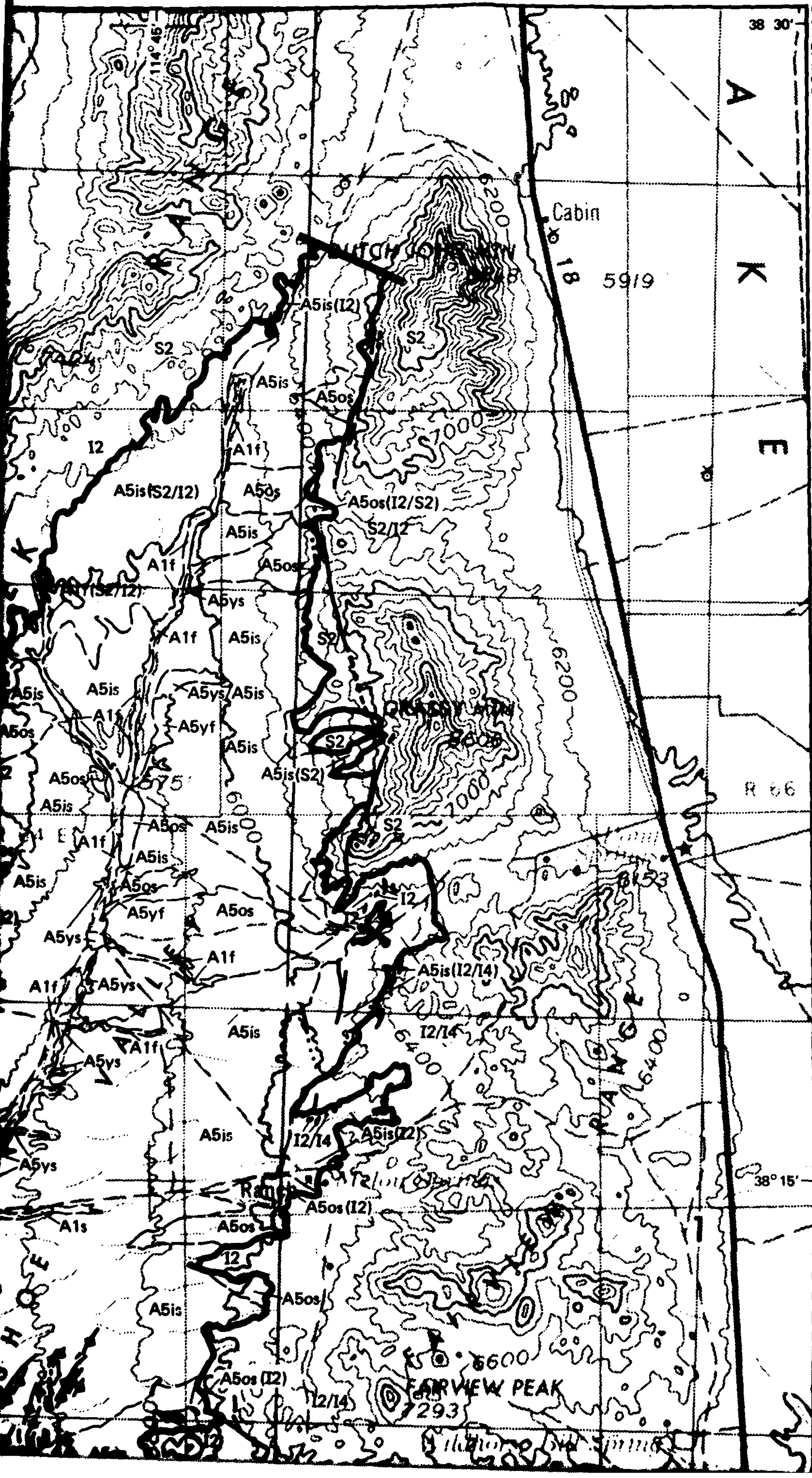
ACTIVITY LOCATIONS
MULESHOE VALLEY, NEVADA

30 JUN 81

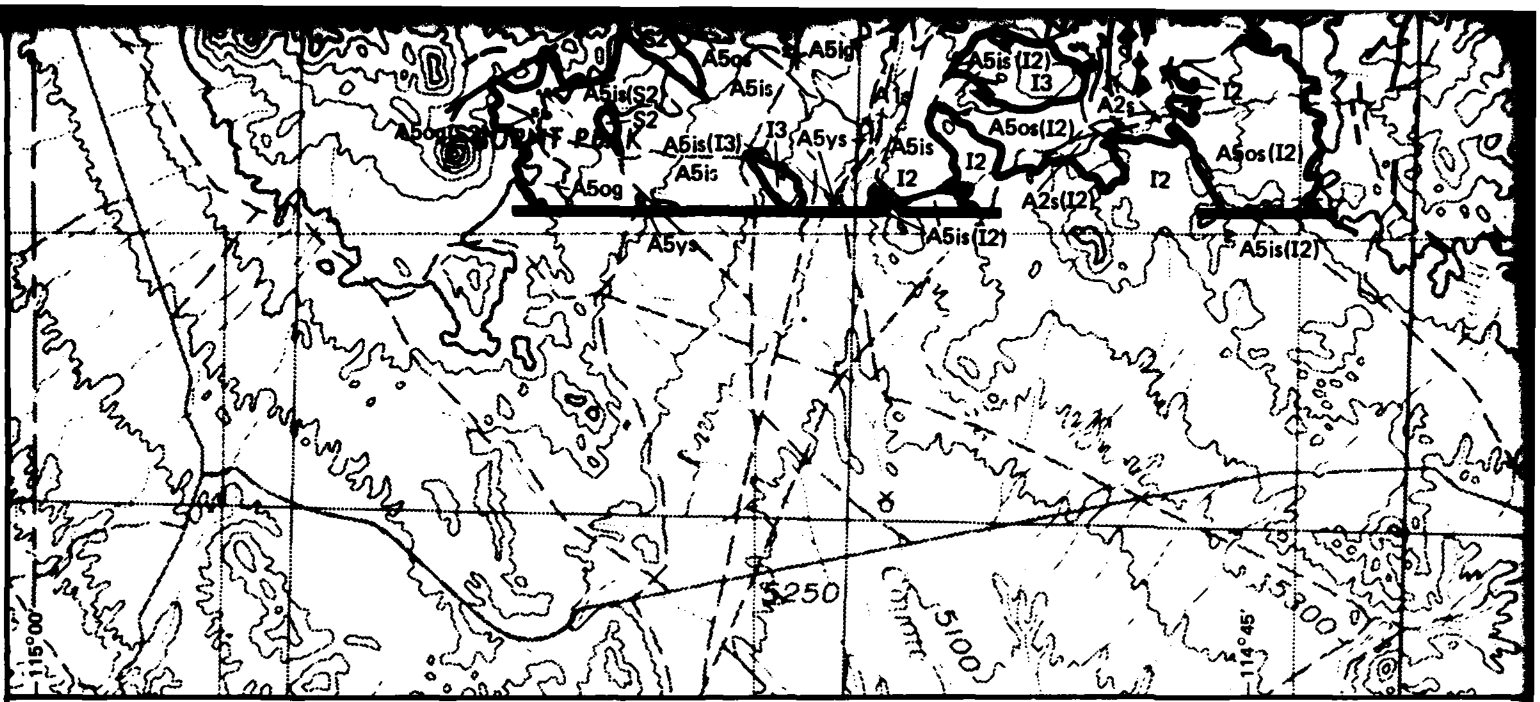
DRAWING 3-1



38°30'
115°00'
114°45'
38°15'
6200
7000
6005
6100
6000
6400
5800
6046
5751
R 63 E
Water
Ranch
S2
S2/I4
S1/S2
I2
I2/I4
A1f
A1s
A1f(S2/I2)
A5is
A5is(I2)
A5is(S2)
A5is(S2/I2)
A5is(S2/I4)
A5is(S1/S2)
A5is/A5ig
A5ig
A5os
A5os(I2)
A5os(S2)
A5ys
A5yf


38° 30'
38° 15'
Cabin
59/9
DUTCH JOHN MTN
A
K
E
A5is(I2)
S2
A5is
A5os
I2
A1f
A5is(S2/I2)
A5os(I2/S2)
S2/I2
A5ys
GRASSY MTN
A5yf
A5is(S2)
A5os
A5yf
A5is(I2/I4)
I2/I4
A5is(I2)
Ranch
A5os (I2)
A1s
FAIRVIEW PEAK
7293
6600
6400
6200
7000
R 66

E-TR-27-MS-I



EXPLANATION

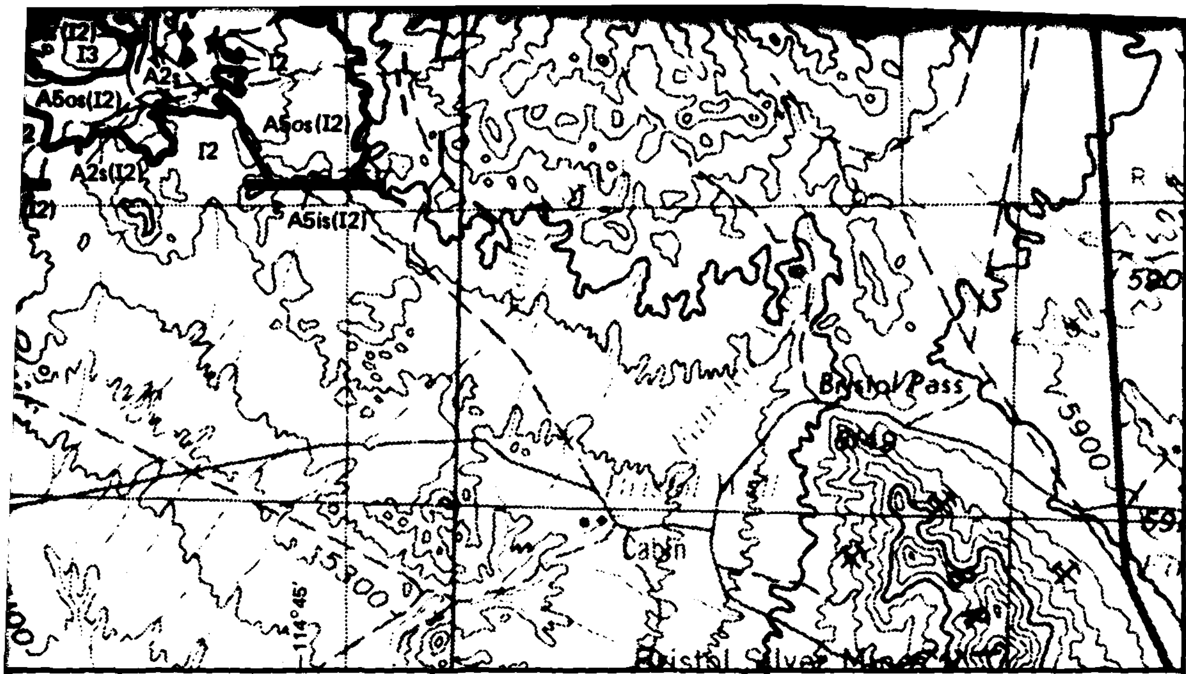
SURFICIAL BASIN – FILL DEPOSITS

A1f A1s	Young fluvial deposits in modern stream channels and on flood plains. A1f - sandy silts and clays; A1s - silty and gravelly sands.
A2s	Old-age incised stream channel and flood-plain deposits in elevated terraces bordering major mod drainages. A2s - silty and gravelly sands.
A5yf A5ys	Young-age alluvial fans where deposition is now occuring. A5yf - sandy silts and clays; A5ys silty and gravelly sands.
A5is A5ig	Alluvial fans of intermediate-age. A5is - silty and gravelly sands; A5ig - sandy gravels.
A5os A5og	Old-age alluvial fans having deep incisions and rounded erosional surfaces. A5os - silty and gravelly sand; A5og - sandy gravels.
A5ys/A5is	Unit designation for areas where two types of deposits are inseparable at map scale. The predominant unit is listed first.
A5is (S2)	A designation for an area where the unit listed first is underlain at shallow depth by parenthetic u

ROCK UNITS

Igneous (I)

I2	Volcanic rocks consisting of undifferentiated units of rhyolite, latite, dacite and andesite.
I3	Volcanic rocks consisting of basalts.



4

EXPLANATION

CIAL BASIN – FILL DEPOSITS

n channels and on flood plains. A1f - sandy silts and clays;

od-plain deposits in elevated terraces bordering major modern
s.

on is now occuring. A5yf - sandy silts and clays;

- silty and gravelly sands; A5ig - sandy gravels.

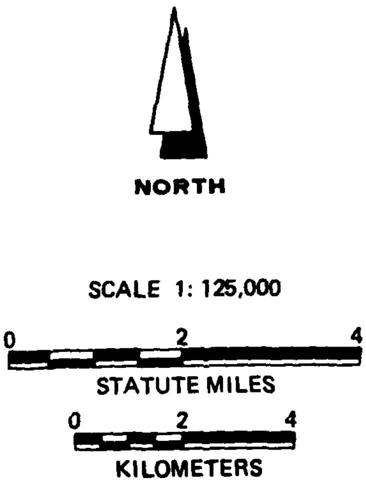
ons and rounded erosional surfaces. A5os - silty and gravelly

types of deposits are inseparable at map scale.

nit listed first is underlain at shallow depth by parenthetic unit.

ROCK UNITS

ntiated units of rhyolite, latite, dacite and andesite.



ROCK UNITS

Igneous (I)

I2	Volcanic rocks consisting of undifferentiated units of rhyolite, latite, dacite and andesite.
I3	Volcanic rocks consisting of basalts.
I4	Volcanic rocks consisting of undifferentiated units of welded tuffs, ash flows, ignimbrites and py

Sedimentary (S)

S1	Sandstone.
S2	Limestone and dolomite.

SYMBOLS

Contact between rock and basin-fill.

Contact between surficial basin-fill or rock units.

Fault, trace of surface rupture, ball on downthrown side, dashed where approximately located in bedrock, dotted where inferred in alluvium.

Tectonic lineament, probably a fault, generally expressed as a linear vegetational growth on aerial photographs.

Valley borders

NOTES:

1. *Surficial basin-fill units pertain only to the upper several feet of soil.* Due to variability of surficial deposits and scale of map presentation, unit descriptions refer to the predominant soil types. Varying amounts of other soil types can be expected within each geologic unit.
2. The distribution of geologic data stations is presented in Volume II Drawing II-1-1. A tabulation of all station data and generalized description of all geologic units is included in Volume II, Section 2.
3. Geology in areas of exposed rock derived from Ertec Western, Inc. (1979, 1980) unpublished data. Tschanz and Pampeyan (1970), and Stewart and Carlson (1978).

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SURFICIAL GEOLOGIC UNITS
MULESHOE VALLEY, NEVADA

30 JUN 81

DRAWING 3-2

5

rhyolite, latite, dacite and andesite.

welded tuffs, ash flows, ignimbrites and pyroclastics.

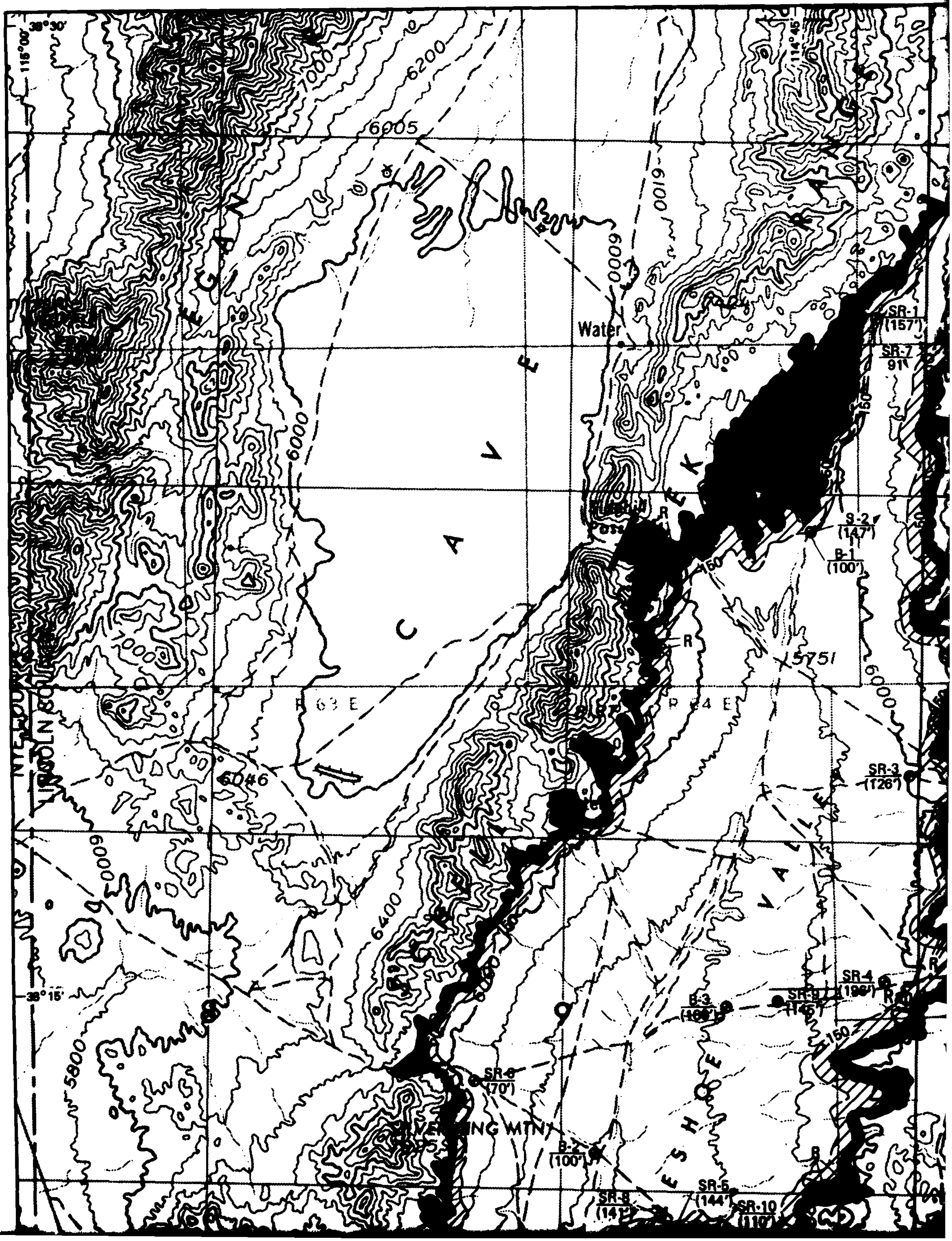
BOLS

side, dashed where approximately located in

essed as a linear vegetational growth on aerial

the upper several feet of soil.
nd scale of map presentation,
nt soil types. Varying amounts
in each geologic unit.
is presented in Volume II
on data and generalized description
me II, Section 2.
d from Ertec Western, Inc.
z and Pampeyan (1970), and Stewart

16



38°30'
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(147')
B-1
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R 63 E
R 64 E
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SR-9
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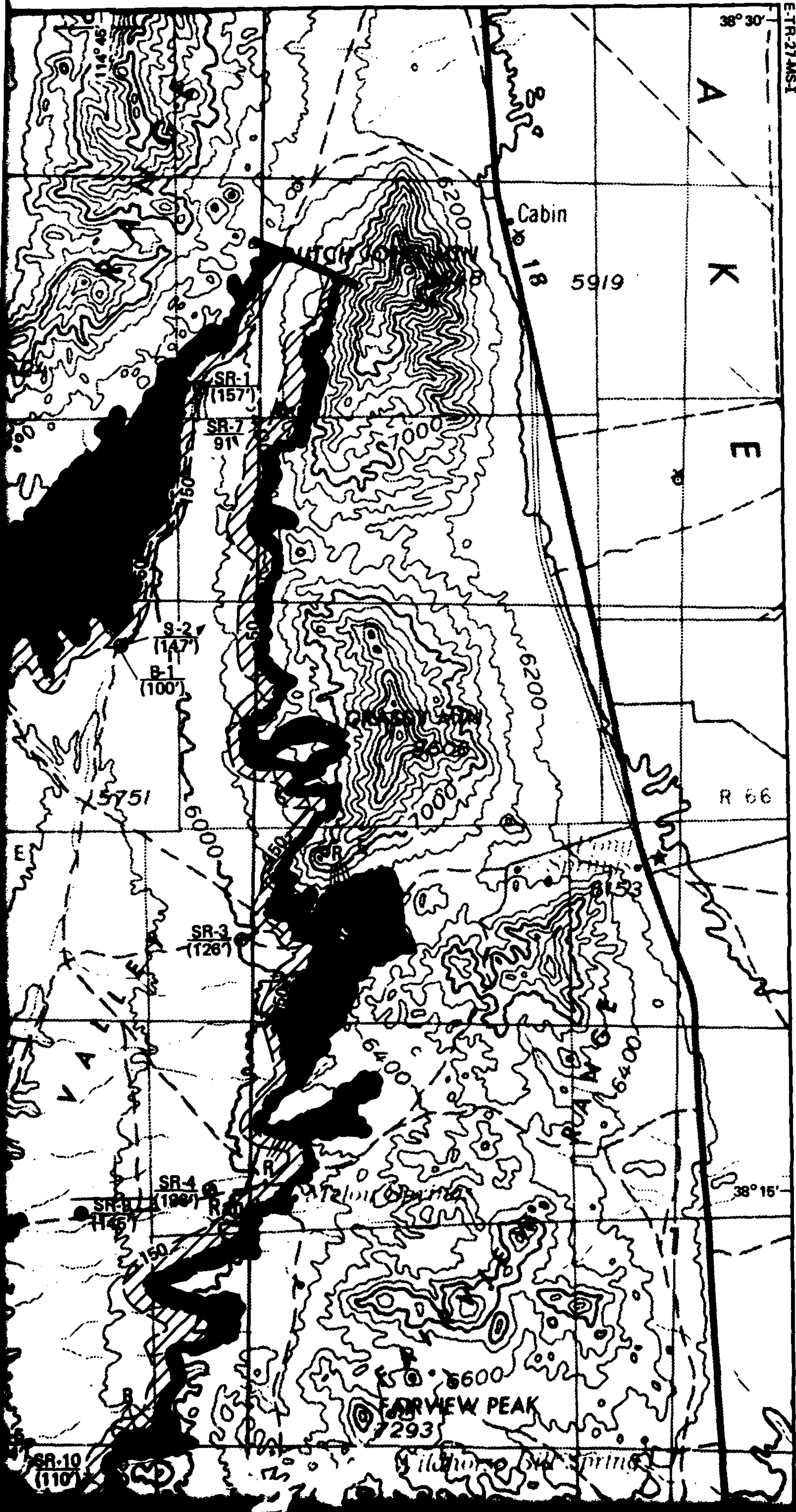
1 2



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R 66
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38° 15'
FAIRVIEW PEAK
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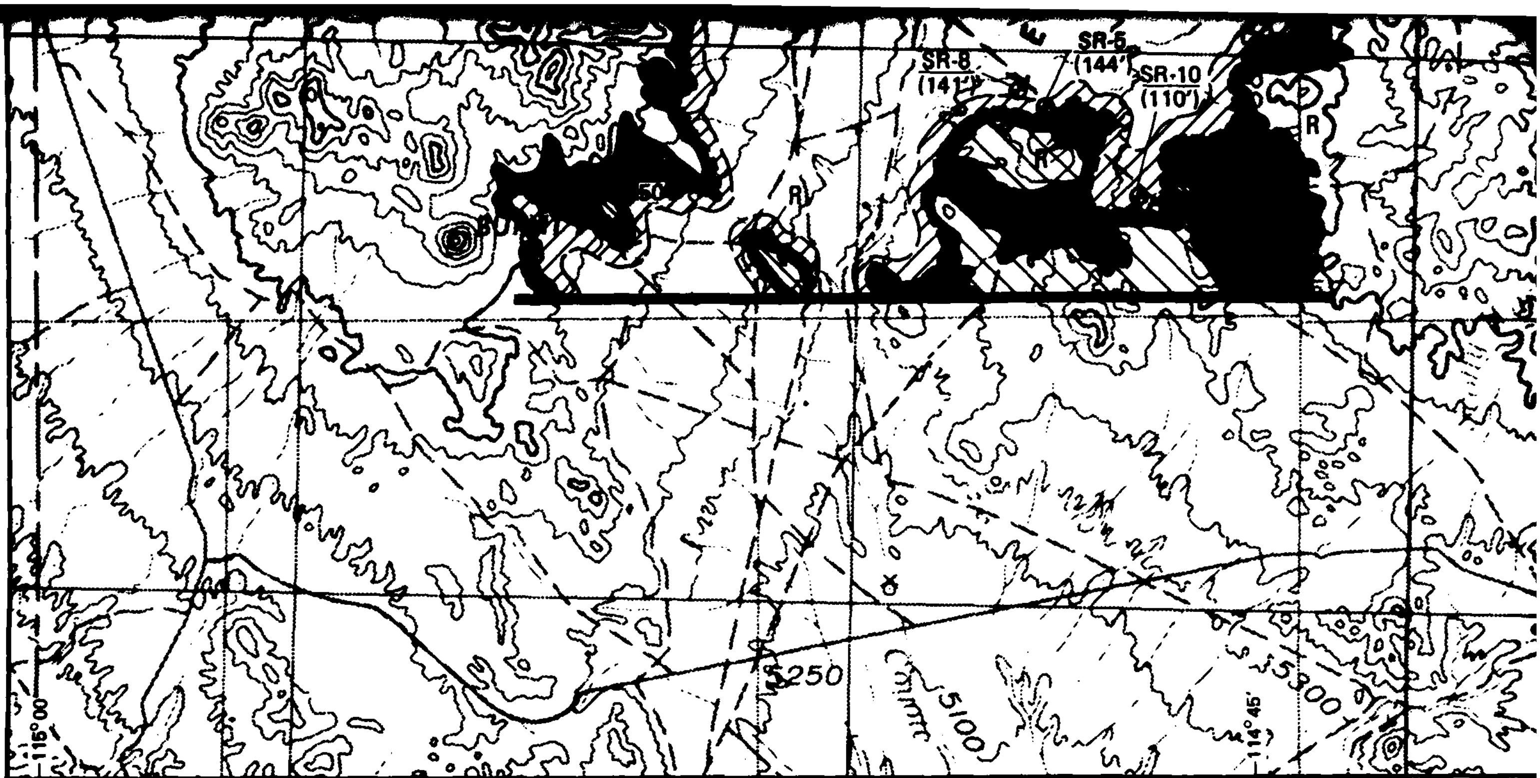

EXPLANATION

50 — Contour indicates rock at a depth of approximately 50 feet (15m) - shading indicates rock less than 50 feet (15m).

150 — Contour indicates rock at a depth of approximately 150 feet (46m) - shading indicates rock between 50 feet (15m) and 150 feet (46m).

Contact between rock and basin-fill.

Valley borders.

Areas of isolated exposed rock.

R — Areas of isolated exposed rock too small for shading.

SR-7 / 199' — Data Source - Seismic refraction line and electrical resistivity sounding (SR); seismic refraction li and/or boring (B);

Depth to rock or, when in parentheses, total depth at which rock not encountered.

NOTE: The contours are based on geologic interpretations and the limited data points shown on the map. Some changes in contour locations can be expected as additional data are obtained.

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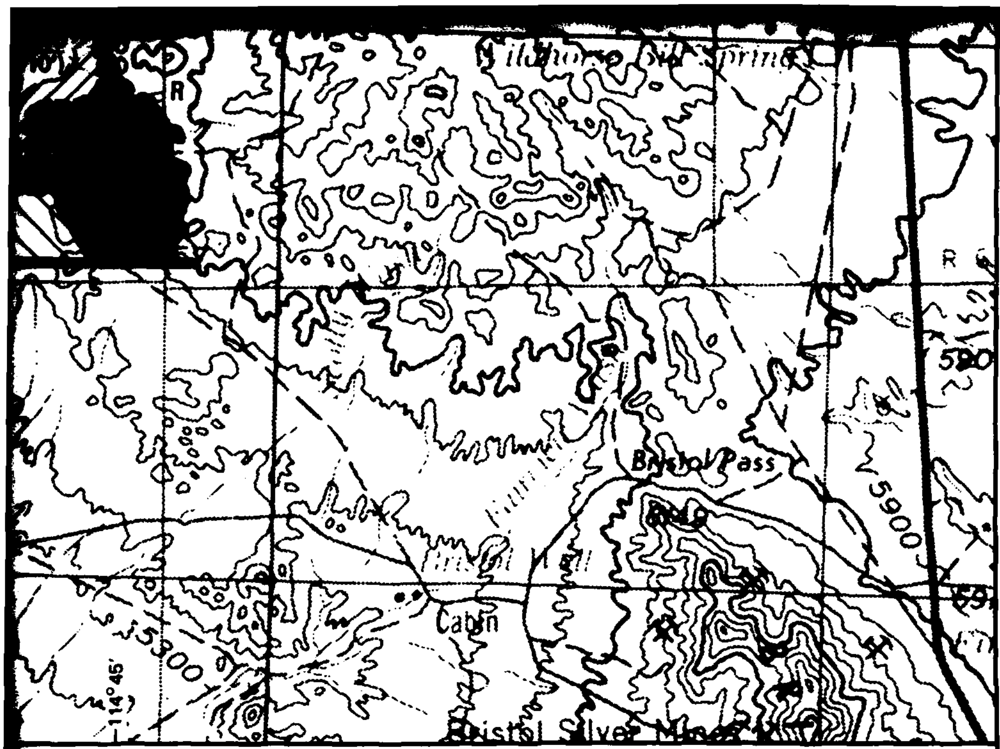
DEPTH TO ROCK
MULESHOE VALLEY, NEVADA

30 JUN 81

DRAWING 3-3

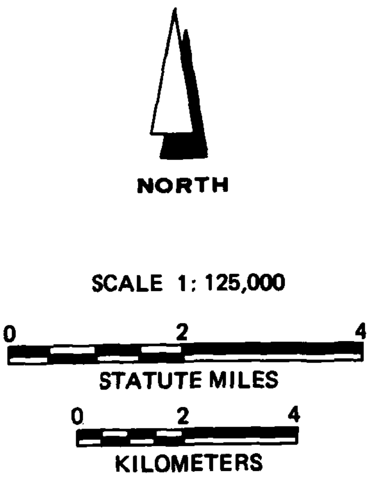


4

TION

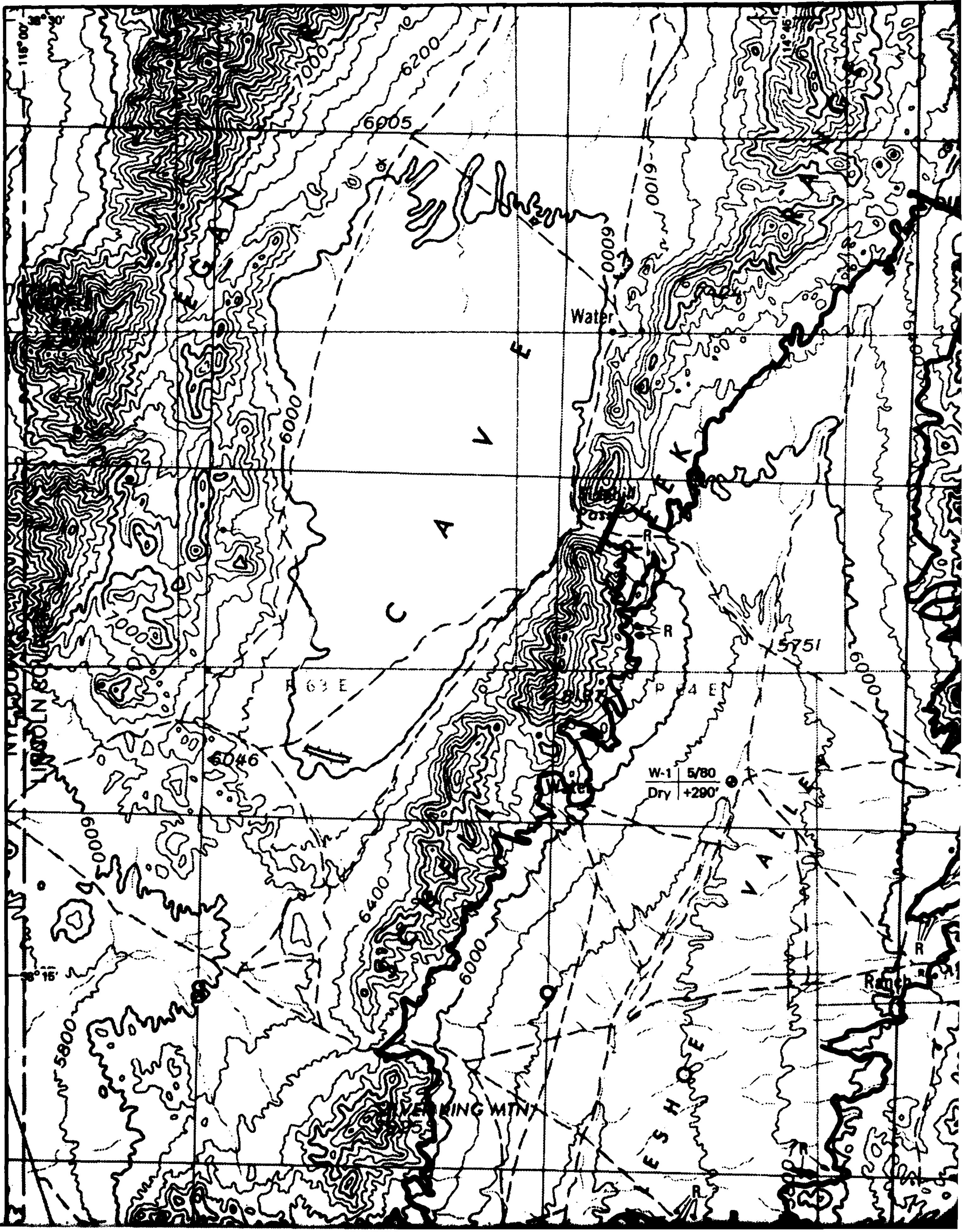
(15m) - shading indicates

t (46m) - shading indicates



y sounding (SR); seismic refraction line (S):

th at which rock not encountered.



6200
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6100
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Water
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R 63 E
R 64 E
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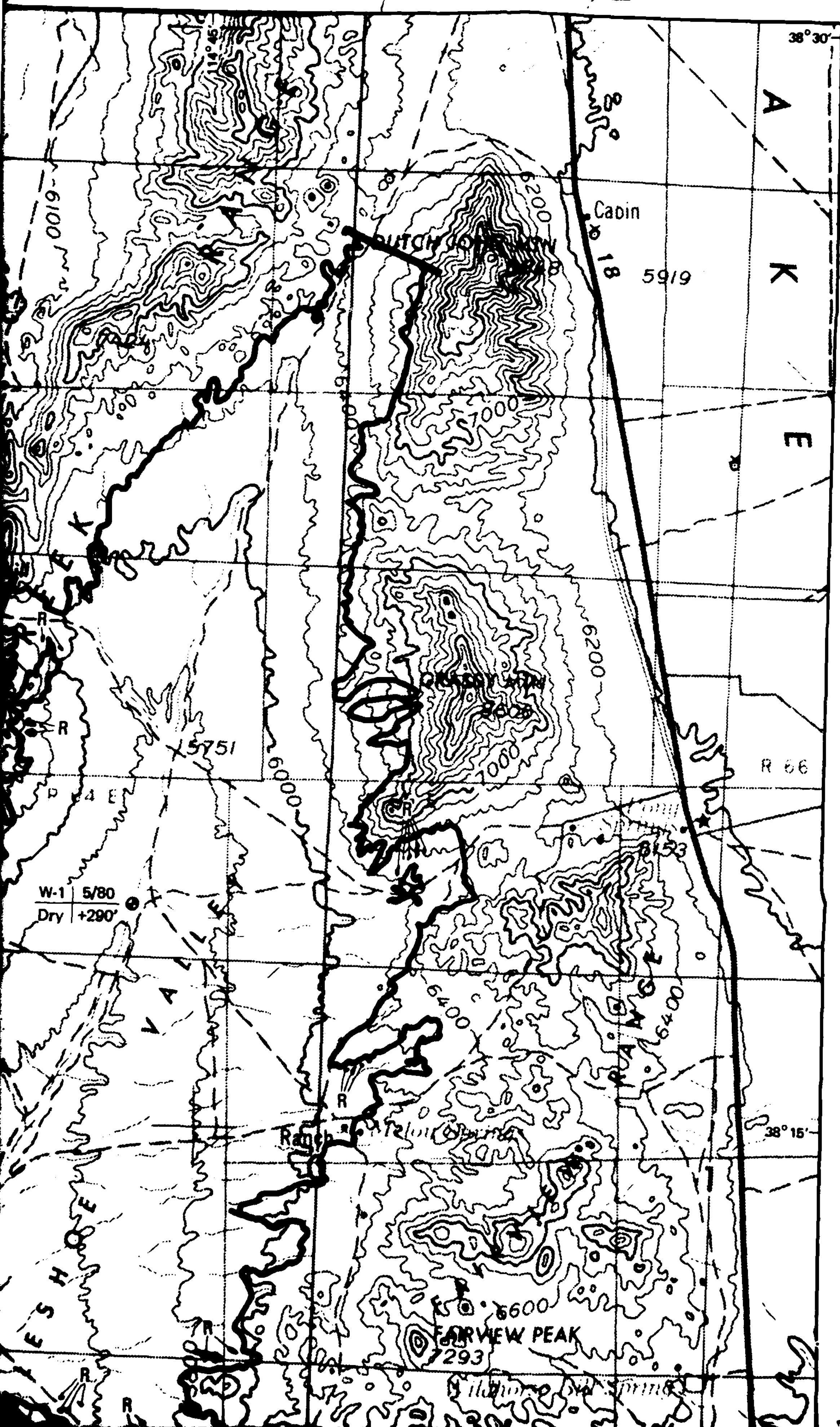
115°00'
38°30'



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FAIRVIEW PEAK
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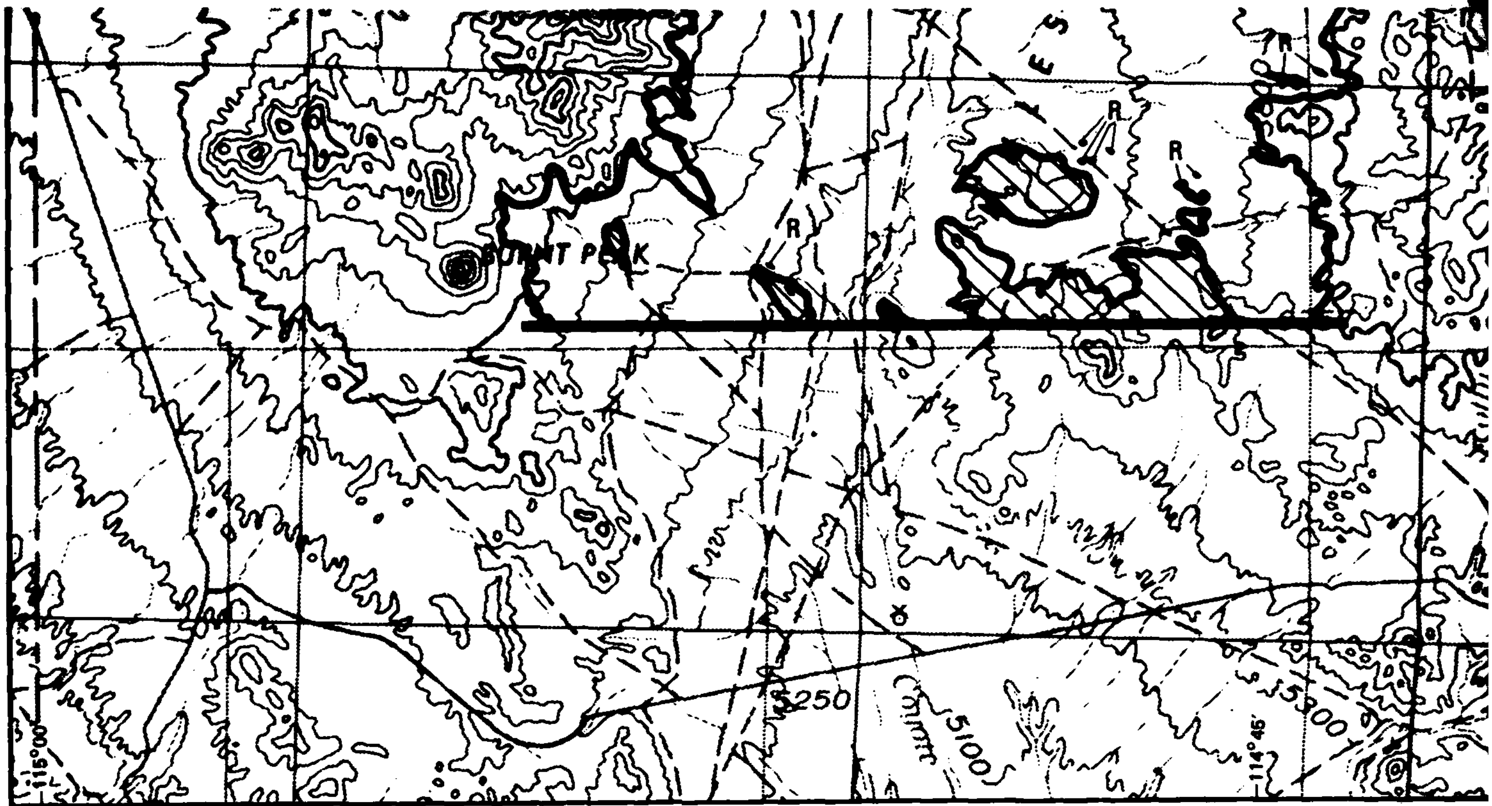
E-TR-27-MS-I



EXPLANATION

Absence of contours indicates ground water occurs at depths greater than 150 feet. Ertec We[illegible] borings, and well data indicate depths to ground water in excess of 300 feet throughout most of Muleshoe Valley (see Volume I, Section 3.0).

Contact between rock and basin-fill.

Valley borders.

Areas of isolated exposed rock.

R — Areas of isolated exposed rock too small for shading.

W-1	5/80
340	394

Data Source - Published water well (W), see Volume II, Table II-3-1.	Month - Year of water level measurement, or year when month unknown.
Depth to water (feet).	Depth of well (feet).

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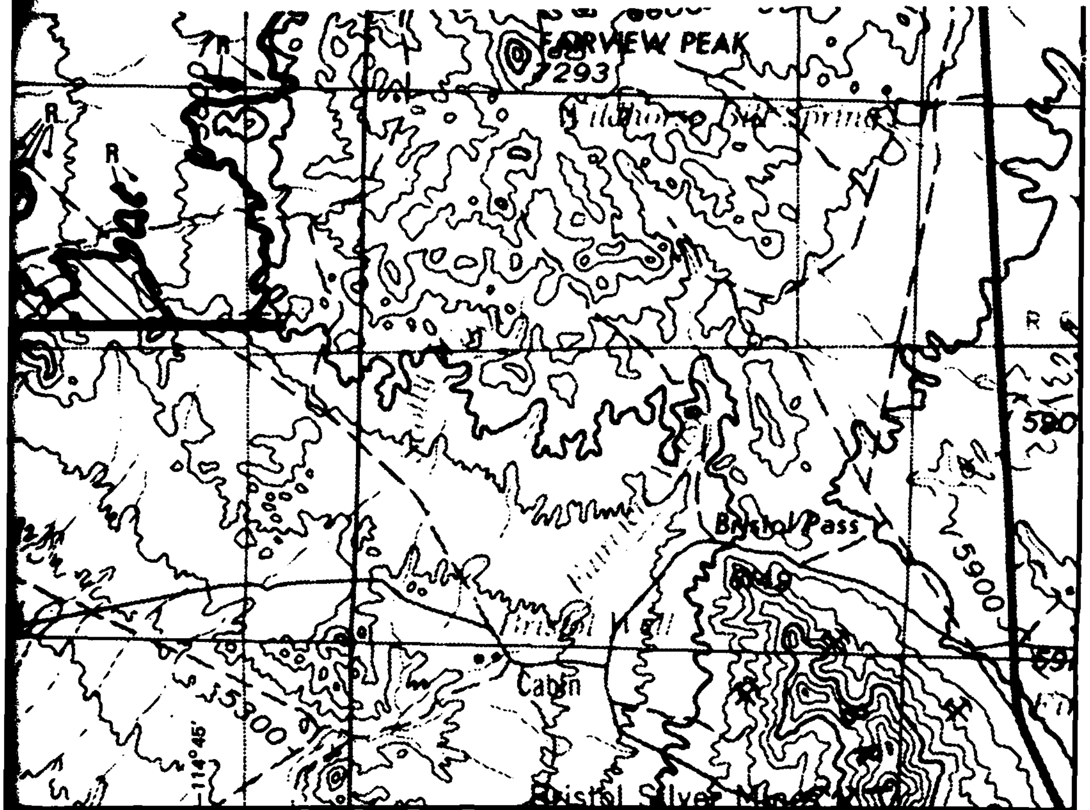
DEPTH TO WATER
MULESHOE VALLEY, NEVADA

30 JUN 81

DRAWING 3-4

3



NATION

t depths greater than 150 feet. Ertec Western, Inc.
er in excess of 300 feet throughout
).

h - Year of water level measurement,
er year when month unknown.
h of well (feet).

NORTH

SCALE 1: 125,000

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STATUTE MILES

0 2 4
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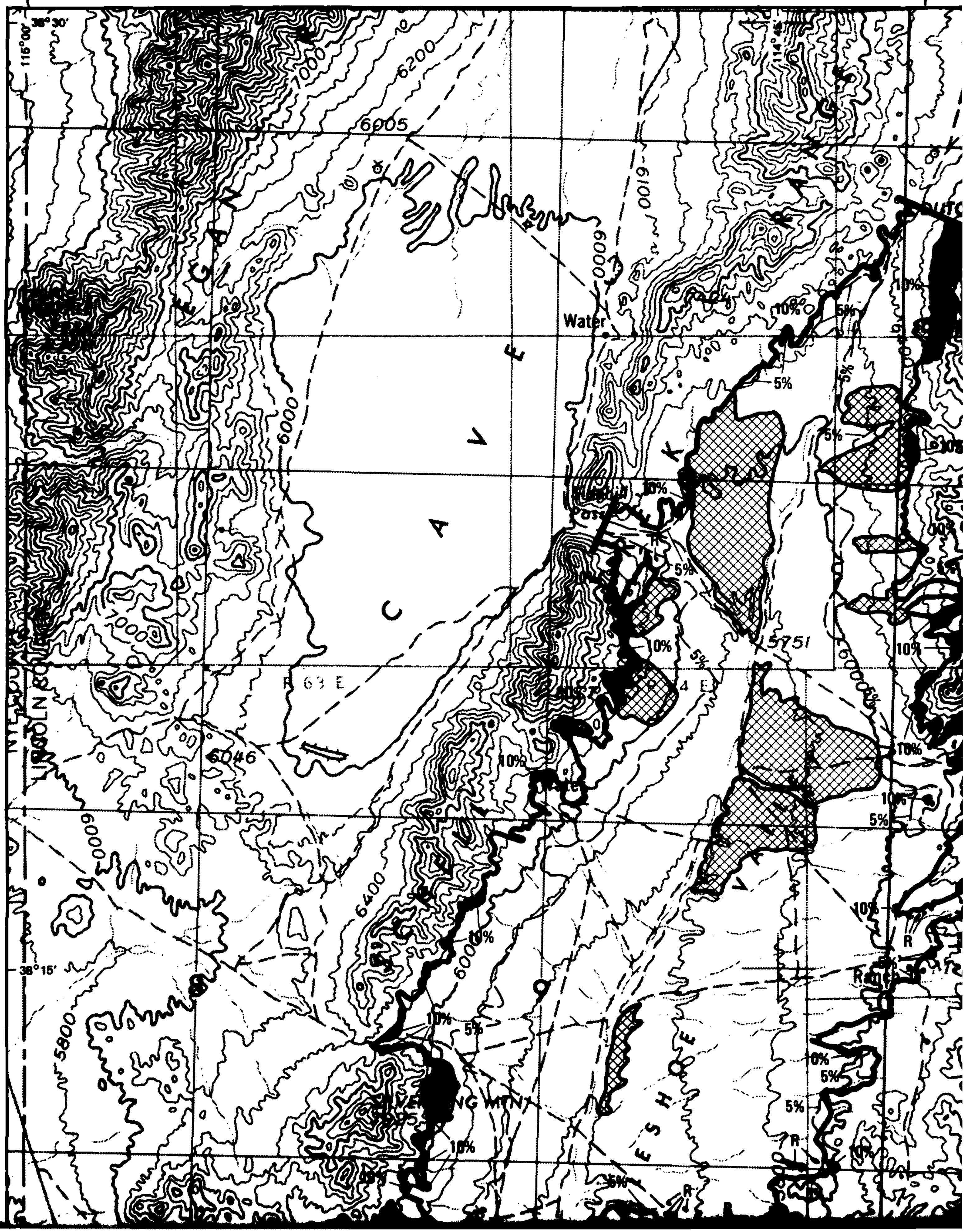

38°30'
116°00'
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Water
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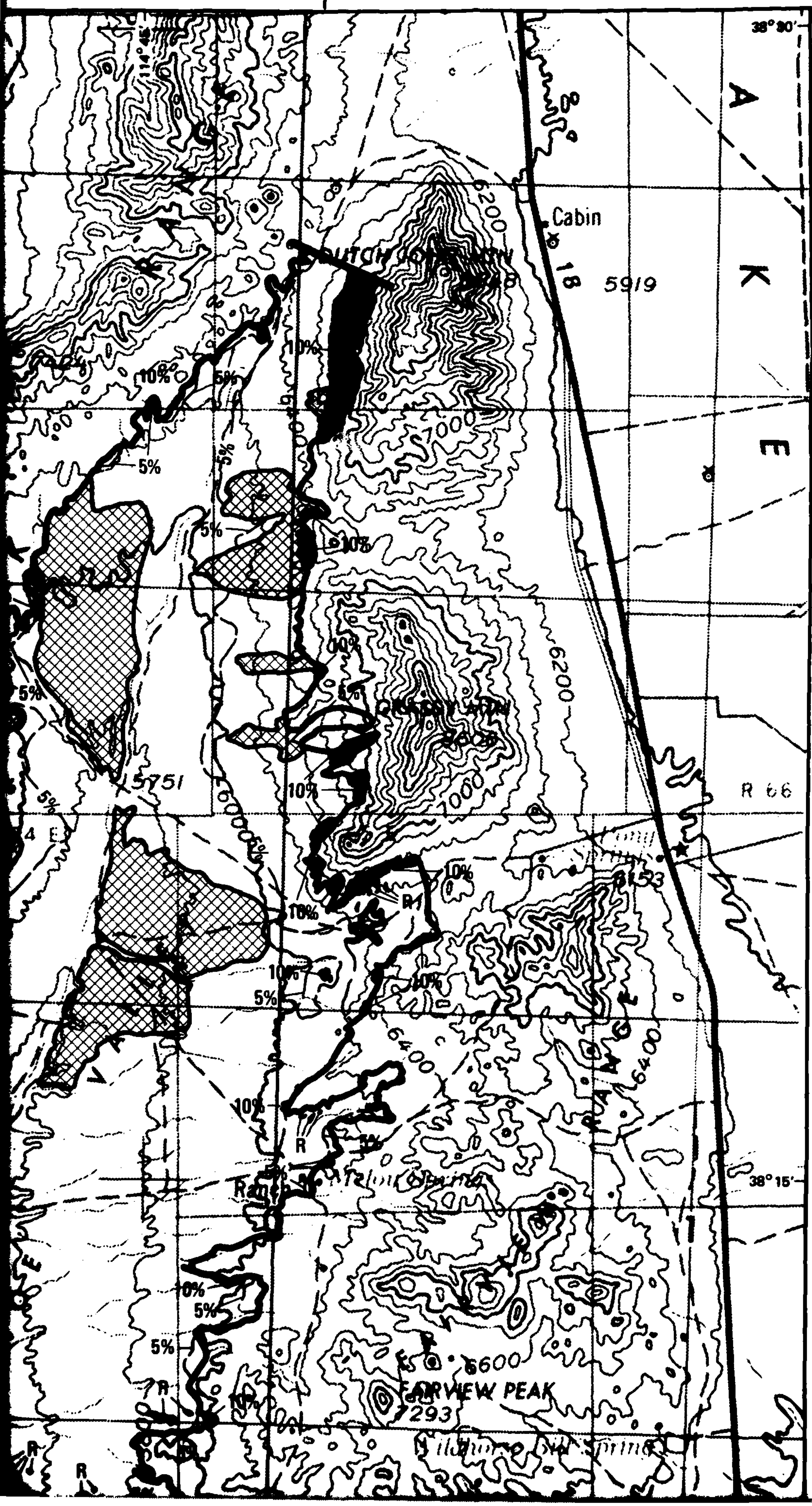
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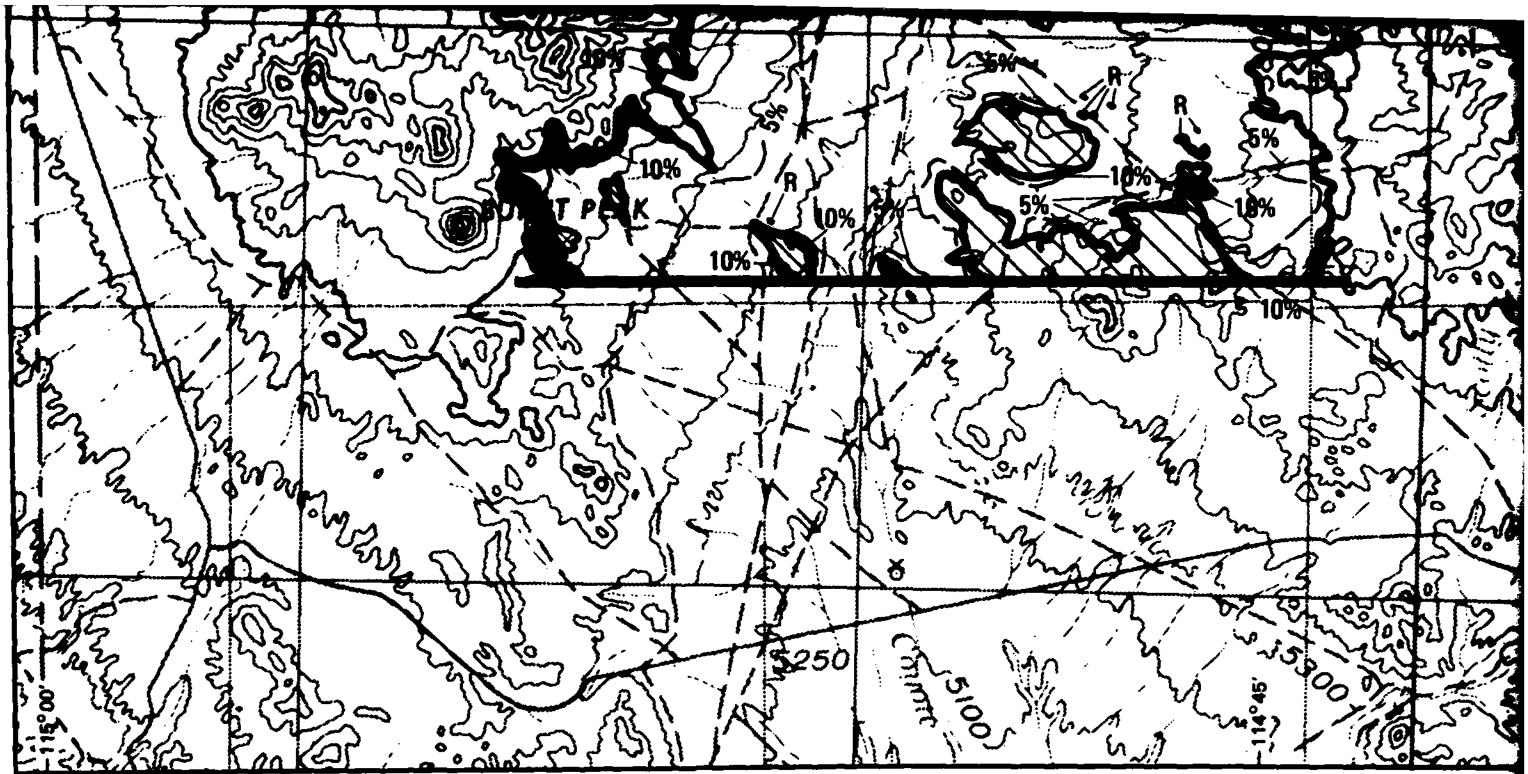
FAIRVIEW PEAK
7293

2



EXPLANATION

Contact between rock and basin-fill.

5% Slope line.

10% Slope line.

Valley border.

Area excluded, on basis of 10% slopes.

Terrain exclusion area.

Areas of isolated exposed rock.

Areas of isolated exposed rock too small for shading.

NOTE: Data used in constructing this map are from: (1) field observations, (2) 1:62,500 USGS topographic maps, and (3) 1:60,000 and 1:25,000 aerial photographs. Due to scale of presentation and variability of terrain conditions, this map is generalized.

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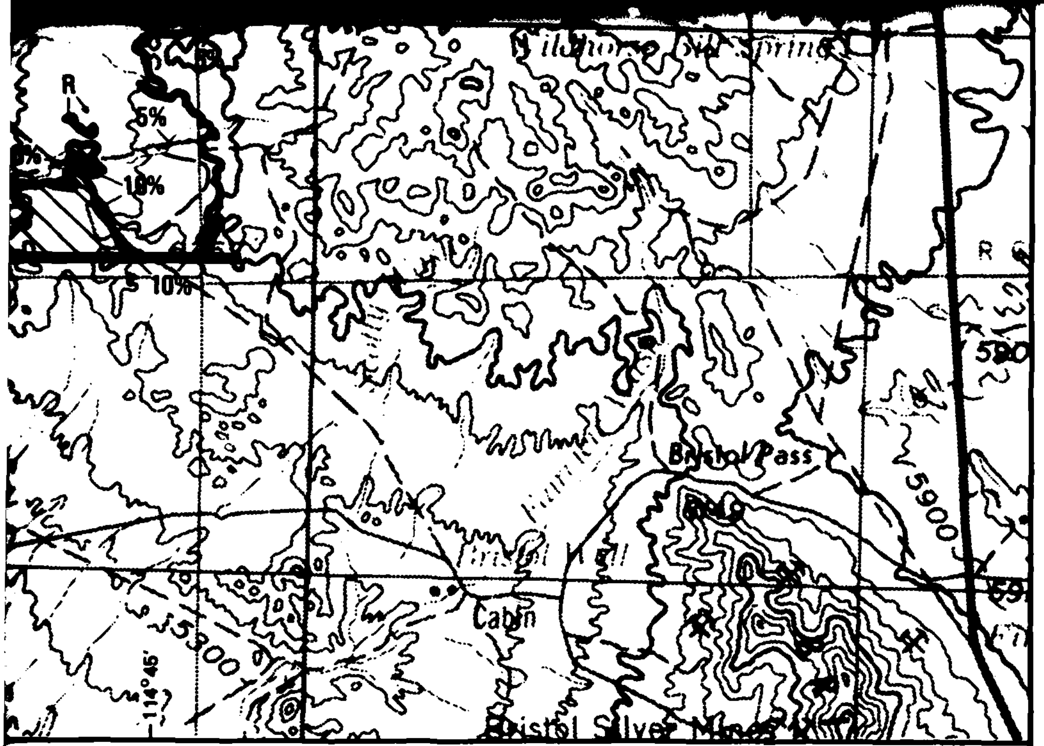
TERRAIN
MULESHOE VALLEY, NEVADA

30 JUN 81

DRAWING 3-6



TION

NORTH

SCALE 1: 125,000

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STATUTE MILES

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al 1:25,000
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4

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APPENDIX

A1.0 GLOSSARY OF TERMS

ACTIVE FAULT - A fault which has had surface displacement within Holocene time (about the last 11,000 years).

ACTIVITY NUMBER - A designation composed of the valley abbreviation followed by the activity type and a unique number: may also be used to designate a particular location in a valley.

ALLUVIAL FAN - A body of stream deposits whose surface approximates a segment of a cone that radiates downslope from the point where the stream leaves a mountainous area and experiences a marked change in gradient resulting in deposition of alluvium.

ALLUVIUM - A general term for a more-or-less stratified deposit of gravel, sand, silt, clay, or other debris, moved by streams from higher to lower ground.

AQUIFER - A permeable saturated zone below the earth's surface capable of conducting and yielding water as to a well.

ARRIVAL - An event; the appearance of seismic energy on a seismic record; a lineup of coherent energy signifying the arrival of a new wave train.

ATTERBERG LIMITS - A general term applied to the various tests used to determine the various states of consistency of fine-grained soils. The four states of consistency are solid, semisolid, plastic, and liquid.

Liquid limit (LL) - The water content corresponding to the arbitrary limit between the liquid and plastic states of consistency of a soil (ASTM D 423-66).

Plastic limit (PL) - The water content corresponding to an arbitrary limit between the plastic and the semisolid states of consistency of a soil (ASTM D 424-59).

Plasticity index (PI) - Numerical difference between the liquid limit and the plastic limit indicating the range of moisture content through which a soil-water mixture is plastic.

BASIN-FILL MATERIAL/BASIN-FILL DEPOSITS - Heterogenous detrital material deposited in a sedimentary basin.

BASE LEVEL - The theoretical limit or lowest level toward which erosion constantly progresses; the level at which neither erosion nor deposition takes place.

BEDROCK - A general term for the rock, usually solid, that underlies soil or other unconsolidated, surficial material. The term is also used here to include the rock composing the local mountain ranges.

BORING - A hole drilled in the ground for the purpose of subsurface exploration.

BOUGUER ANOMALY - The residual value obtained after latitude, elevation, and terrain corrections have been applied to gravity data.

BOULDER - A rock fragment, usually rounded by weathering and abrasion with an average diameter of 12 inches (305 mm) or more.

BULK SAMPLE - A disturbed soil sample (bag sample) obtained from cuttings brought to the ground surface by a drill rig auger or obtained from the walls of a trench excavation.

c - Cohesion (Shear strength of a soil not related to interparticle friction).

CALCAREOUS - Containing calcium carbonate; presence of calcium carbonate is commonly identified on the basis of reaction with dilute hydrochloric acid.

CALICHE - In general, secondary calcium carbonate cementation of unconsolidated materials occurring in arid and semiarid areas.

CALIFORNIA BEARING RATIO (CBR) - The ratio (in percent) of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed rock base material (ASTM D 1883-73). During the CBR test, the load is applied on the circular penetration piston (3 inches^2 base area [19 cm^2]) which is penetrated into the the soil sample at a constant penetration rate of 0.05 inch/minute (1.2 mm/min). The bearing ratio reported for the soil is normally the one at 0.1 inch (2.5 mm) penetration.

CLAST - An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering (disintegration) of a larger rock mass.

CLAY - Fine-grained soil (passes No. 200 sieve [0.074 mm]) that can be made to exhibit plasticity within a range of water contents and that exhibits considerable strength when air-dried.

CLAY SIZE - That portion of the soil finer than 0.002 mm.

CLOSED BASIN - A catchment area draining to some depression or lake within its area from which water escapes only by evaporation or infiltration into the subsurface.

COARSE-GRAINED (or granular) - A term which applies to a soil of which more than one-half of the soil particles, by weight, are larger than 0.074 mm in diameter (No. 200 U.S. sieve size).

COARSER-GRAINED - A term applied to alluvial fan deposits which are predominantly composed of material (cobble) larger than 3 inches (76 mm) in diameter.

COBBLE - A rock fragment, larger than a pebble and smaller than a boulder, having a diameter between 3 and 10 inches (64 and 256 mm), being somewhat rounded or otherwise modified by abrasion in the course of transport.

COMPACTION TEST - A test to determine the relationship between the moisture content and density of a soil sample which is prepared in compacted layers at various water contents (ASTM D 1557-70).

COMPRESSIBILITY - Property of a soil pertaining to its susceptibility to decrease in volume when subjected to load.

COMPRESSIONAL WAVE -An elastic body wave in which particle motion is in the direction of propagation: the type of seismic wave assumed in conventional seismic exploration. Also called P-wave, dilatational wave, and longitudiral wave.

CONDUCTIVITY - The ability of a material to conduct electrical current. In isotropic material, conductivity is the reciprocal of resistivity. Units are mhos per meter.

CONE PENETROMETER TEST - A method of evaluating the in-situ engineering properties of soil by measuring the penetration resistance developed during the steady slow penetration of a cone (60^{o} apex angle, 10-cm^2 projected area) into soil.

Cone resistance or end bearing resistance, q_c - The resistance to penetration developed by the cone, equal to the vertical force applied to the cone divided by its horizontally projected area.

Friction resistance, f_s - The resistance to penetration developed by the friction sleeve, equal to the vertical force applied to the sleeve divided by its surface area. This resistance consists of the sum of friction and adhesion.

Friction ratio, f_R - The ratio of friction resistance to cone resistance, f_s/q_c, expressed in percent.

CONSISTENCY - The relative ease with which a soil can be deformed.

CONSOLIDATION TEST - A type of test to determine the compressibility of a soil sample. The sample is enclosed in the consolidometer which is then placed in the loading device. The load is applied in increments at certain time intervals and the change in thickness is recorded.

CORE SAMPLE - A cylindrical sample obtained with a rotating core barrel with a cutting bit at its lower end. Core samples are obtained from indurated deposits and in rock.

DEGREE OF SATURATION - Ratio of volume of water in soil to total volume of voids.

DIRECT SHEAR TEST - A type of test to measure the shear strength of a soil sample where the sample is forced to fail on a predetermined plane.

DISSECTION/DISSECTED (alluvial fans) - The cutting of stream channels into the surface of an alluvial fan by the movement (or flow) of water.

DRY UNIT WEIGHT/DRY DENSITY - Weight per unit volume of the solid particles in a soil mass.

ELECTRICAL CONDUCTIVITY - Ability of a material to conduct electrical current.

ELECTRICAL RESISTIVITY - Property of a material which resists flow of electrical current.

EOLIAN - A term applied to materials which are deposited by wind.

EPHEMERAL (stream) - A stream or reach of a stream that flows briefly only in direct response to precipitation in the immediate locality, and whose channel is at all times above the water table.

EXTERNAL DRAINAGE - Stream drainage system whose down-gradient flow is unrestricted by any topographic impediments.

EXTRUSIVE ROCK - Igneous rock that has been ejected onto the earth's surface (e.g., lava, basalt, rhyolite, andesite, detrital material, volcanic tuff, pumice).

FAULT - A plane or zone of fracture along which there has been displacement.

FAULT BLOCK MOUNTAINS - Mountains that are formed by normal faulting in which the surface crust is divided into partially to entirely fault-bounded blocks of different elevations.

FINE-GRAINED - A term which applies to a soil of which more than one-half of the soil particles, by weight, are smaller than 0.074 mm in diameter (passing the No. 200 U.S. size sieve).

FINER-GRAINED - A term applied to alluvial fan deposits which are composed predominantly of material less than 3 inches (76 mm).

FLUVIAL DEPOSITS - Material produced by river action; generally loose, moderately well-graded sands and gravel.

FORMATION - A mappable assemblage of rocks characterized by some degree of homogeneity or distinctiveness.

FUGRO DRIVE SAMPLE - A 2.50-inch-(6.4-cm) diameter soil sample obtained from a drill hole with a Fugro drive sampler. The Fugro drive sampler is a ring-lined barrel sampler containing 12 one-inch-(2.54-cm) long brass sample rings. The sampler is advanced into the soil using a drop hammer.

GEOMORPHOLOGY - The study, classification, description, nature, origin, and development of present landforms and their relationships to underlying structures and of the history of geologic changes as recorded by these surface features.

GEOPHONE - The instrument used to transform seismic energy into electrical voltage; a seismometer, jug, or pickup.

GRABEN - An elongated crustal block that has been downthrown along faults relative to the rocks on either side.

GRAIN-SIZE ANALYSIS (GRADATION) - A type of test to determine the distribution of soil particle sizes in a given soil sample. The distribution of particle sizes larger than 0.074 mm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 0.074 mm is determined by a sedimentation process using a hydrometer.

GRANULAR - See Coarse-Grained.

GRAVEL - Particles of rock that pass a 3-inch (76.2 mm) sieve and are retained on a No. 4 (4.75 mm sieve).

GRAVITY - The force of attraction between bodies because of their mass. Usually measured as the acceleration of gravity.

GYPSIFEROUS - Containing gypsum, a mineral consisting mostly of calcium sulfate.

HORST - An elongated crustal block that has been uplifted along faults relative to the rocks on either side.

INTERIOR DRAINAGE - Stream drainage system that flows into a closed topographic low (basin).

INTRUSIVE (rock) - A rock formed by the process of emplacement of magma (liquid rock) in preexisting rock, (e.g., granite, granodiorite, quartz monzonite).

LACUSTRINE DEPOSITS - Materials deposited in a lake environment.

LINE - A linear array of observation points, such as a seismic line.

LINEAMENT - A linear topographic feature of regional extent that is thought to reflect crustal structure.

LIQUID LIMIT - See ATTERBERG LIMITS.

LOW STRENGTH SURFICIAL SOIL - Soil which will perform poorly as a road subgrade at its present consistency when used directly beneath a road section.

MOISTURE CONTENT - The ratio, expressed as a percentage, of the weight of water contained in a soil sample to the oven-dried weight of the sample.

N VALUE - Penetration resistance, described as the number of blows required to drive the standard split-spoon sampler for the second and third 6 inches (0.15 m) with a 140-pound (63.5-kg) hammer falling 30 inches (0.76 m) (ASTM D 1586-67).

OPTIMUM MOISTURE CONTENT - Moisture content at which a soil can be compacted to a maximum dry unit weight by a given compactive effort.

P-WAVE - See Compressional Wave.

PATINA (Desert Varnish) - A dark coating or thin outer layer produced on the surface of a rock or other material by weathering.

PAVEMENT/DESERT PAVEMENT - When loose material containing pebble-sized or larger rocks is exposed to rainfall and wind action, the finer dust and sand are blown or washed away and the pebbles gradually accumulate on the surface, forming a mosaic which protects the underlying finer material from wind attack. Pavement can also develop in finer-grained materials. In this case, the armored surface is formed by dissolution and cementation of the grains involved.

PERCHED GROUND WATER - Unconfined ground water separated from an underlying main body of ground water by an unsaturated zone.

PERMEABILITY - The property of soil and/or rock material which permits liquid to pass through.

pH - An index of the acidity or alkalinity of a soil in terms of the logarithm of the reciprocal of the hydrogen ion concentration.

PHI (Ø) - Angle of internal friction.

PIEZOMETRIC SURFACE - An imaginary surface representing the static head of ground water and defined by the level to which water will rise in a well.

PITCHER TUBE SAMPLE - An undisturbed, 2.87-inch- (73-mm) diameter soil sample obtained from a drill hole with a Pitcher tube sampler. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit depending upon the hardness of the material being penetrated.

PLASTIC LIMIT - See ATTERBERG LIMITS.

PLASTICITY INDEX - See ATTERBERG LIMITS.

PLAYA/PLAYA DEPOSITS - A term used in the southwest U.S. for a dried-up, flat-floored area composed of thin, evenly stratified sheets of clay, silt, or fine sand, and representing the lowest part of a shallow, completely closed or undrained, desert lake basin in which water accumulates and is quickly evaporated, usually leaving deposits of soluble salts.

POORLY GRADED - A descriptive term applied to a coarse-grained soil if it consists predominantly of one particle size (uniformly graded) or has a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

RANGE-BOUNDING FAULT - Usually a normal fault in which one side has moved up relative to the other and which separates the mountain front from the valley.

RELATIVE AGE - The relationship in age (oldest to youngest) between geologic units without specific regard to number of years.

RESISTIVITY (True, Intrinsic) - The property of a material which resists the flow of electric current. The ratio of electric-field intensity to current density.

ROCK UNITS - Distinct rock masses with different characteristics (e.g., igneous, metamorphic, sedimentary).

ROTARY WASH DRILLING - A boring technique in which advancement of the hole through overburden is accomplished by rotation of a heavy string of rods while continuous downward pressure is maintained through the rods on a bit at the bottom of the hole. Water or drilling mud is forced down the rods to the bit, and the return flow brings the cuttings to the surface.

S-WAVE - See Shear Wave.

SAND - Soil passing through No. 4 (4.75 mm) sieve and retained on No. 200 (0.075 mm) sieve.

SAND DUNE - A low ridge or hill consisting of loose sand deposited by the wind, found in various desert and coastal regions and generally where there is abundant surface sand.

SEISMIC - Having to do with elastic waves. Energy may be transmitted through the body of an elastic solid as P-waves (compressional waves) or S-waves (shear waves).

SEISMIC LINE - A linear array of travel time observation points (geophones). In this study, each line contains 24 geophone positions.

SEISMIC REFRACTION DATA: - Data derived from a type of seismic shooting based on the measurement of seismic energy as a function of time after the shot and of distance from the shot, by determining the arrival times of seismic waves which have traveled nearly parallel to the bedding in high-velocity layers in order to map the depth to such layers.

SEISMOGRAM - A seismic record.

SEISMOMETER - See Geophone.

SHEAR STRENGTH - The maximum resistance of a soil to shearing (tangential) stresses.

SHEAR WAVE - A body wave in which the particle motion is perpendicular to the direction of propagation. Also called S-Wave or transverse wave.

SHEET FLOW - A process in which stormborne water spreads as a thin, continuous veneer (sheet) over a large area.

SHEET SAND - A blanket deposit of sand which accumulates in shallow depressions or against rock outcrops, but does not have characteristic dune form.

SHOT - Any source of seismic energy; e.g., the detonation of an explosive.

SHOT POINT - The location of any source of seismic energy; e.g., the location where an explosive charge is detonated in one hole or in a pattern of holes to generate seismic energy. Abbreviated SP.

SILT - Fine-grained soil passing the No. 200 sieve (0.074 mm) that is nonplastic or very slightly plastic and that exhibits little or no strength when air-dried.

SILT SIZE - That portion of the soil finer than 0.02 mm and coarser than 0.002 mm.

SITE - Location of some specific activity or reference point.

SPECIFIC GRAVITY - The ratio of the weight in air of a given volume of soil solids at a stated temperature to the weight in air of an equal volume of distilled water at a stated temperature.

SPLIT-SPOON SAMPLE - A disturbed sample obtained with a split-spoon sampler with an outside diameter of 2.0 inches (5.1 cm). The sample consists of a split barrel which is driven into the soil using a drop hammer.

SPREAD - The layout of geophone groups from which data from a single shot are recorded simultaneously. Spreads containing 24 geophones have been used in Fugro's seismic refraction surveys.

STREAM CHANNEL DEPOSITS - See Fluvial Deposits.

STREAM TERRACE DEPOSITS - Stream channel deposits no longer part of an active stream system, generally loose, moderately well graded sand and gravel.

SULFATE ATTACK - The process during which sulfates, salts of sulfuric acid, contained in ground water cause dissolution and damage to concrete.

SURFICIAL DEPOSIT - Unconsolidated residual colluvial and alluvial deposits occurring on or near the earth's surface.

TEST PIT - An excavation made to depths of about 5 feet (1.5 m) by a backhoe. A test pit permits visual examination of undisturbed material in place.

TRENCH - An excavation by a backhoe to depths of about 15 feet (4.5 m). A trench permits visual examination of soil in place and evaluaton of excavation wall stability.

TRIAXIAL COMPRESSION TEST - A type of test to measure the shear strength of an undisturbed soil sample (ASTM D2850-70). To conduct the test, a cylindrical specimen of soil is surrounded by a fluid in a pressure chamber and subjected to an isotropic pressure. An additional compressive load is then applied, directed along the axis of the specimen called the axial load.

Consolidated-drained (CD) Test - A triaxial compression test in which the soil was first consolidated under an all-around confining stress (test chamber pressure) and was then compressed (and hence sheared) by increasing the vertical stress. Drained indicates that excess pore water pressures generated by strains are permitted to dissipate by the free movement of pore water during consolidation and compression.

Consolidated-undrained (CU) Test - A triaxial compression test in which essentially complete consolidation under the confining (chamber) pressure is followed by a shear at constant water content.

UNCONFINED COMPRESSION - A type of test to measure the compressive strength of an undisturbed sample (ASTM D 2166-66). Unconfined compressive strength is defined as the load per unit area at which an unconfined prismatic or cylindrical specimen of soil will fail in a simple compression test.

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) - A system which determines soil classification for engineering purposes on the basis of grain-size distribution and Atterberg limits.

VALLEY FILL - See Basin-Fill Material/Basin-Fill Deposits.

VELOCITY - Refers to the propagation rate of a seismic wave without implying any direction. Velocity is a property of the medium and not a vector quantity when used in this sense.

VELOCITY LAYER - A layer of rock or soil with a homogeneous seismic velocity.

VELOCITY PROFILE - A cross section showing the distribution of material seismic velocities as a function of depth.

WASH SAMPLE - A sample obtained by screening the returned drilling fluid during rotary wash drilling.

WATER TABLE - The upper surface of an unconfined body of water at which the pressure is equal to the atmospheric pressure.

WELL-GRADED - A soil is identified as well-graded if it has a wide range in grain size and substantial amounts of most intermediate sizes.

Definitions were derived from the following references:

American Society for Testing and Materials, 1976, Annual book of ASTM standards, Part 19: Philadelphia, American Soc. for Testing and Materials, 484 p.

Fairbridge, Rhodes W., ed., 1968, The enclyclopedia of geomorphology: Stroudsburg, Pennsylvania, Dowden, Hutchinson, and Ross, Inc., 1295 p.

Gary, M., McAfee, R., Jr., Wolf, C. L., eds., 1972, Glossary of geology: Washington, D.C., American Geol. Institute, 805 p.

Merriam, G., and Merriam, C., 1977, Webster's new collegiate dictionary: Springfield, Mass., G. and C. Merriam Co., 1536 p.

Sheriff, R. E., 1973, Encyclopedic dictionary of exploration geophysics: Tulsa, Oklahoma, Soc. of Exploration Geophysicists, 266 p.

A2.0 EXCLUSION CRITERIA

The exclusion criteria used during the Verification Studies are based on both geotechnical and cultural considerations. Land excluded for geotechnical reasons includes areas of shallow rock, shallow water, and adverse terrain. Cultural exclusions include areas near towns, lands already withdrawn from public use, and regions with potentially high economic value. The exclusion criteria are defined in Table A2-1.

CRITERIA		DEFINITION AND COMMENTS
SURFACE ROCK AND ROCK OCCURRING WITHIN 50 FEET (15m) AND 150 FEET (46m) OF THE GROUND SURFACE		Rock is defined as any earth material which is not rippable by conventional excavation methods. Where available, seismic P-wave velocities were evaluated in the determination of rock conditions.
SURFACE WATER AND GROUND WATER OCCURRING WITHIN 50 FEET (15m) AND 150 FEET (46m) OF THE GROUND SURFACE		Surface water includes all significant lakes, reservoirs, swamps, and major perennial streams. Water which would be encountered in a 50-foot and 150-foot excavation was considered in the application of this criterion. Depths to ground water resulting from deeper confined aquifers were not considered.
TERRAIN	Percent Grade	Areas having surface gradients exceeding 10 percent or a preponderance of slopes exceeding 10 percent as determined from maps at scales of 1 :125 000, 1 :62 500, and 1 :24 000 and by field observation.
	Drainage	Areas averaging two or more 10-foot deep drainages per 1000 feet (measured parallel to contours, as determined from maps at scales of 1 :24,000 or in the field).
CULTURAL	Quantity/Distance:	Eighteen nautical mile exclusion arcs from cities having populations (1970) of 25,000 or more. Three nautical mile exclusion arcs from cities having populations (1970) of between 5,000 and 25,000.
	Land Use:	All significant federal and state forests, parks, monuments, and recreational areas. All significant federal and wildlife refuges, grasslands, ranges, preserves and management areas. Indian reservations.

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EXCLUSION CRITERIA
VERIFICATION STUDIES, NEVADA – UTAH

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TABLE A2-1

A3.0 ENGINEERING GEOLOGIC PROCEDURES

The principal objectives of the field geology investigation were to:

1. Delineate surficial extent of soil types and geologic units;
2. Assess terrain conditions; and
3. Make observations helpful i: efining depth to rock and water.

Aerial photographs (1:60,000 scale black and white; 1:25,000 scale color) served as the base on which all mapping was done. Field activities were directed toward checking the photogeologic mapping.

Field checking consisted chiefly of collecting data about surficial soils at selected locations in order to refine contacts and define engineering characterisitics of photogeologic units. At each location, observations of grain-size distribution, color, clast lithology, surface soil development, and a variety of engineering parameters were recorded (see Volume II, Geotechnical Data). Observations were made in existing excavations (borrow pits, road cuts, stream cuts) or in hand-dug test pits. Extrapolation of this data, to determine surficial extent, was accomplished by geologic reconnaissance over existing roads.

Of the parameters listed, grain size is the most important for engineering purposes and, for this reason, is included in the geologic unit designation. However, grain size is not readily mapped on aerial photos, and much of the field work involved determination of the extent of surficial deposits of a particular grain-size category (gravel, sand, or fine-grained).

Terrain data were also taken at geologic field stations. Drainage width and depth were estimated and predominant surface slope was measured. Slopes were measured over a distance of 100 to 150 feet (31 to 46 m) with an Abney hand level. For additional data, depths of major drainages encountered during geologic reconnaissance between stations were recorded on the aerial photographs.

To help refine depth to rock interpretations, observations were concentrated along the basin margin to identify areas of shallow rock. Observations regarding depth to water were restricted to measurements in existing wells and identification of areas with water at the surface.

A4.0 GEOPHYSICAL PROCEDURES

A4.1 SEISMIC REFRACTION SURVEYS

A4.1.1 Instruments

Field explorations were performed with a 24-channel SIE Model RS-44 seismic refraction system which consisted of 24 amplifiers coupled with a dry-write, galvanometer-type recording oscillograph. Seismic energy was detected by Mark Products Model L-10 geophones with natural frequency of 4.5 Hz. Geophones were fitted with short spikes to provide good coupling with the ground. Cables with two takeout intervals were used to transmit the detected seismic signal from the geophones to the amplifiers. Time of shot was transmitted from shotpoint to recording system via an FM radio link.

The degree of gain was set on the amplifiers by the instrument operators and was limited by the background noise at the time of the shot. The amplifiers are capable of maximum gain of 1.1 million. The oscillograph placed timing lines on the seismograms at 0.01-second intervals. The timing lines form the basis for measuring the time required for the energy to travel from the shot to each geophone.

A4.1.2 Field Procedures

Each seismic refraction line consisted of a single spread of 24 geophones with a distance of 410 feet (125 m) between end points. Geophone spacing provided six intervals of 25 feet (7.6 m) at both ends of the line and 11 central intervals of 10 feet (3 m). Six shots were made per spread at locations 65 feet (20 m), 190 (58 m), and 305 feet (93 m) left and right of the spread center. The recording system was located between geophones 12 and 13.

The explosive used was "Kinestik" which was transported to the site as two nonexplosive components, a powder and a liquid. The components were mixed in the field to make an explosive compound. Charges ranged in size from one-third to five pounds and were buried from 1 to 5 feet (0.3 to 1.5 m) deep. Charges were detonated using Reynold's exploding bridge wire (EBW) detonators instead of conventional electric blasting caps. Use of EBWs provides maximum safety against accidental detonation and extremely accurate "time breaks" (instant of detonation). Relative elevations of geophones and shotpoints were obtained by level or transit where lines had more than 2 or 3 feet (0.6 to 0.9 m) of relief.

A4.1.3 Data Reduction

The travel times for compressional waves from the shots to the geophones were obtained from the seismograms by visual inspection. These times were plotted at their respective horizontal

distances and best fit lines were drawn through the points to obtain apparent velocities for materials below the seismic line.

A combination of delay time and ray tracing methods was used in a computer program to obtain depth to refracting horizons from the time-distance information.

A4.2 ELECTRICAL RESISTIVITY SURVEYS

A4.2.1 Instruments

Electrical resistivity measurements were made with a Bison Instrument model 2350B resistivity meter which provides current to the earth through two electrodes and measures the potential (voltage) drop across two other electrodes.

A4.2.2 Field Procedures

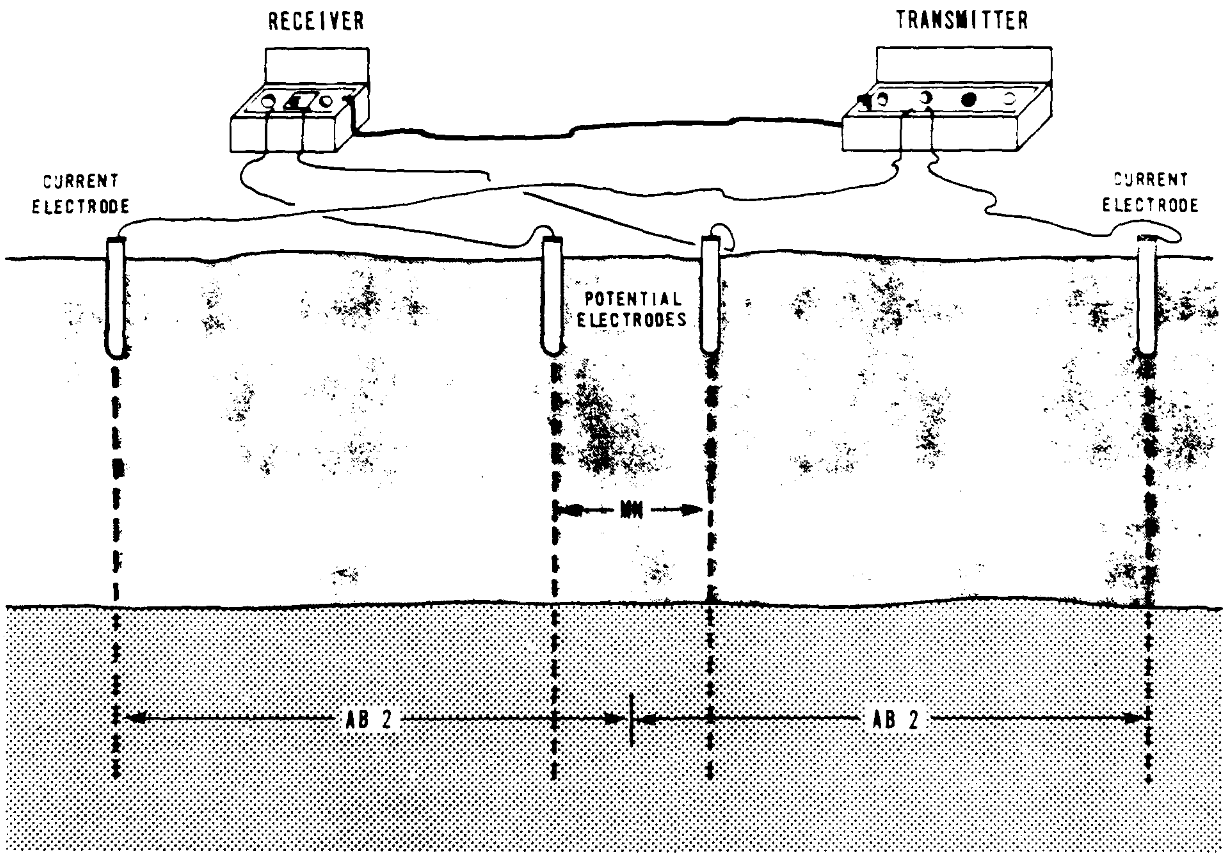
Electrical resistivity soundings were made using the Schlumberger electrode arrangement. Soundings are made by successive resistivity measurements which obtain information from deeper and deeper materials. The depth of penetration of the electrical current is made greater by increasing the distance between the current electrodes. The arrangement of electrodes in the Schlumberger method is shown in Figure A4-1. The four electrodes are in a line with the two current electrodes on the ends. The distance between the current electrodes (AB) is always five or more times greater than the distance between the potential electrodes (MN).

The initial readings are made with MN equal to 5 feet (1.5 m) and AB equal to 30 feet (9 m). Successive readings were made with AB at 40, 50, 60, 80, 100, 120, 160, 200, 300, 400, 500, and 600 feet (12, 15, 18, 24, 30, 37, 49, 61, 91, 122, 152, and 183 m). MN spacing is sometimes increased one or two times as AB is expanded. This increase is required when the signal drops to a level below the meter's sensitivity. The potential drop is greater between more widely spaced electrodes (MN), so increasing MN increases the signal. When it becomes necessary to increase MN, the spacing of AB is reduced to the spacing of the previous reading. MN is then increased, and a measurement is made. This provides two resistivity measurements at the same AB spacing but with different MN spacings.

A4.2.3 Data Reduction

Each apparent resistivity value is plotted versus one-half the current electrode spacing (AB/2) used to obtain it. Log-log graph paper is used to form the coordinates for the graph. A smooth curve is drawn through the points. This sounding curve forms the basis for interpreting the resistivity layering at the sounding location.

E-TR-27-MS-I



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SCHLUMBERGER ARRAY
ELECTRICAL RESISTIVITY SOUNDINGS
VERIFICATION VALLEYS, NEVADA-UTAH

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FIGURE A4-1

A computer program that does iterative "curve-matching" is used to develop a layer model that has a theoretical resistivity curve that is similar to the field curve. Input to the program is generated by digitizing the field curve with an electronic digitizer.

A5.0 ENGINEERING PROCEDURES

Soil engineering activities consisted of the following:

1. Field activities:
   - o Borings
   - o Trenches
   - o Test Pits
   - o Surficial Samples
   - o Cone Penetrometer Tests
2. Office activities:
   - o Laboratory Tests
   - o Data Analyses and Interpretations

The procedures used in the various activities are described in the following sections.

A5.1 BORINGS

A5.1.1 Drilling Techniques

The borings were drilled at designated locations using rotary techniques.

The drilling rig was a truck-mounted Failing 1500 with hydraulic pulldown. The borings were nominally 4-7/8 inches (124 mm) in diameter and 100 feet (30 m) deep. A bentonite-water slurry was used to return soil cuttings to the surface. A tricone drill bit was used for coarse-grained soils and a drag bit for drilling in fine-grained soils.

A5.1.2 Method of Sampling

A5.1.2.1 Sampling Intervals

Soil samples were obtained at the following nominal depths as well as at depths of change in soil type:

0' to 10'	(0.0 to 3.0 m)	- Pitcher or drive - samples at 3' intervals
10' to 30'	(3.0 to 9.1 m)	- Pitcher or drive - samples at 5' intervals
30' to 100'	(9.1 to 30.5 m)	- Pitcher or drive - samples at 10' intervals

A5.1.2.2 Sampling Techniques

a. Ertec Drive Samples: Ertec drive samplers were used to obtain relatively undisturbed soil samples. The Fugro drive sampler is a ring-lined barrel sampler with an outside diameter of 3.0 inches (76.2 mm) and inside diameter of 2.50 inches (63.5 mm). It contains 12 individual 1-inch- (25.4-mm) long

rings and is attached to a 12-inch- (30-cm) long waste barrel. The sampler was advanced using a downhole hammer weighing 300 pounds (136 kg) with a drop of 24 inches (61.0 cm).

The number of blows required to advance the sampler for a 6-inch (15-cm) interval were recorded. Samples obtained were retained in the rings, placed in plastic bags with manually twisted top ends, and sealed in plastic sample containers. Each sample was identified with a label indicating job number, boring number, sample number, depth range, Unified Soil Classification Symbol (USCS), and date. Ring samples were placed in foam-lined steel boxes.

b. Pitcher Samples: The Pitcher sampler was used to obtain undisturbed soil samples. The primary components of this sampler are an outer rotating core barrel with a bit and an inner stationary, spring-loaded, thin-wall sampling tube which leads or trails the outer barrel drilling bit, depending on the hardness of the material penetrated. The average inside diameter of the sampling tubes used was 2.87 inches (73 mm). Before placing the Pitcher tube in the outer barrel, the tube was inspected for sharpness and protrusions.

The Pitcher sampler was then lowered to the bottom of the boring, and the thin-walled sampling tube advanced into the soil ahead of the rotating cutting bit by the weight of the drill rods and hydraulic pulldown. The thin-walled sampling tube was retracted into the core barrel and the sampler was brought to the surface. After removal of the sampling tube from the core barrel, the length of the recovered soil sample was measured and recorded. Before preparing and sealing the tube, the drilling fluid in the Pitcher tube was removed. Cap plugs were taped in place on the top and bottom of the Pitcher tube and sealed with wax. When Pitcher samples could not be retrieved without disturbance, they were clearly marked as "disturbed." Each sealed Pitcher tube was labeled as explained under "Ertec Drive Samples" and then placed vertically in foam-lined wooden boxes.

c. Bulk Samples: Bulk samples from rotary drilling were obtained by screening the returning drilling fluid to obtain wash samples. Recovered samples were placed in plastic bags and labeled as previously explained.

A5.1.3 Logging

All soils were classified in the field by the procedures outlined in Section A5.5, "Field Visual Soil Classification," of this Appendix. Rock encountered in the borings was described according to classifications given in Travis (1955) and Folk (1974). The following general information was entered on the boring logs at the time of drilling: boring number; project name, number, and location; name of drilling company and driller; name of logger and date logged; and method of drilling and sampling, drill bit type and size, driving weight

and average drop as applicable. As drilling progressed, the soil samples recovered were visually classified as outlined in Section A5.5, "Field Visual Soil Classification," and the description was entered on the logs. Section A5.5 also discusses other pertinent data and observations made, which were entered on the boring logs during drilling.

A5.1.4 Sample Storage and Transportation

Samples were handled with care, drive sample containers being placed in foam-lined steel boxes, while Pitcher samples were transported in foam-lined wooden boxes. Particular care was exercised by drivers while traversing rough terrain to avoid disturbing the undisturbed samples. Whenever ambient air temperatures fell below 32°F, all samples were stored in heated rooms during the field work and transported to Ertec Western's Long Beach laboratory in heated cabins in back of pickup trucks.

A5.2 GROUND-WATER OBSERVATION WELLS

A5.2.1 Purpose

Ground-water observation wells were installed to determine:

a. The elevation of the ground-water surface or table and its variation with the season of the year,

b. The location of perched water tables,

c. The location of aquifers, and

d. The presence of artesian pressures.

A5.2.2 Drilling Equipment

See Section A5.1.2 for a complete description.

A5.2.3 Procedure

a. Installed ground-water observation well (casing 2-inch [51-mm] PVC pipe) in wells (4 7/8-inch [124-mm] diameter) drilled at the designated locations using rotary wash techniques.

b. The wells were drilled to the depths specified on the field maps (150 or 200 feet [45.7 or 61.0 m]) or to 30 feet (9.1 m) below the water table, if determinable at the time of drilling.

c. REVERT drilling mud (bio-degradable) or equivalent, where practical, was used. If the REVERT mud was not adequate for returning gravelly cuttings to the surface, then a thin normal mud was used.

d. Obtained wash samples every 10 feet (3.0 m) or at changes in the soil type. Prepared boring log, placed samples in a plastic bag, and labelled each sample.

e. Described all samples in detail on the log for each well. Filled out the sample inventory sheets.

f. Upon completion of the well, the prepared 2-inch (51-mm) PVC casing was inserted to the bottom of the well and the well was flushed clean of drilling mud and loose cuttings by circulating water down the casing.

g. When flushing was complete (clear return water), the PVC casing was raised so that its bottom end was approximately 5 feet (1.5 m) above the bottom of the boring. Carefully holding the PVC casing in position; pea gravel was back-filled to approximately 30 feet (9.1 m) above the bottom of the PVC casing.

h. About 2 feet (0.6 m) of the PVC casing was left above the ground surface. The activity locations and well number were written on PVC with a felt tip marker. Vented the well cutting a 3-inch vertical slot at the top of the PVC with hacksaw. Cap the well. Installed a 2-inch x 4-inch x 36-inch long wooden board or standard metal fence post adjacent to the well to prevent cattle from breaking the PVC. Painted the top of the post with an orange spray paint.

i. To prevent the entrance of surface water into the well, sealed and back-filled the top 3 to 4 feet (0.9 to 1.2 m) with cuttings, empty mud sacks, small bentonite mud cakes, and local dry soil. Sloped the fill (local surface soil) at the top of the hole away from the pipe.

A5.3 TRENCHES, TEST PITS, AND SURFICIAL SAMPLES

A5.3.1 Excavation Equipment

The trenches, test pits, and surficial samples were excavated using a rubber tire-mounted Case 580C backhoe with a maximum depth capability of 14 feet (4.3 m).

A5.3.2 Method of Excavation

Unless caving occurred during the process of excavation, the trench width was nominally 2 feet (0.6 m). Trench depths were typically 14 feet (4.2 m), and lengths ranged from 10 to 16 feet (3.0 to 4.9 m). Test pits were nominally 2 feet (0.6 m) wide, 5 feet (1.5 m) deep, and ranged from 5 to 10 feet (1.5 to 3.0 m) in length. Surficial sample excavations were typically 2 feet (0.6 m) wide, 2 feet (0.6 m) deep, and about 3 to 5 feet (0.9 to

1.5 m) long. The trench and test pit walls were vertical. However, where surface materials were unstable, the trench walls were sloped back to a safe angle to prevent sloughing during the completion of excavation and logging. The excavated material was deposited on one side at least 4 feet (1.2 m) from the edge of the trenches in order to minimize stress loads at the edges. The excavations were backfilled with the excavated material and the ground surface was restored to a condition as conformable with the surrounding terrain as practicable.

A5.3.3 Sampling

The following sampling procedures were generally followed for all trenches, test pits, and surficial samples:

- Representative bulk soil samples (large or small) were obtained in the top 2 feet (0.6 m). If the soil type changed in the top 2 feet, bulk samples of both the soil types were obtained. In addition, bulk samples of all soil types encountered at different depths in the excavation were obtained. For each soil type in the top 2 to 3 feet (0.6 to 0.9 m), two large bulk samples, weighing about 50 pounds (22.7 km) each were taken. Bulk samples from other depths were limited to one bag. When soils from two locations were similar, only a small bag sample weighing about 2 pounds (0.9 kg) was taken from the second location.

- All large bulk samples were placed first in plastic bags and then in cloth bags. The small bulk samples were placed in small plastic bags. All sample bags of soil were tied tightly at the top to prevent spillage and tagged with the following information: project number; trench, test pit, or surficial sample number; bulk sample number; depth range in feet; Unified Soil Classification symbol: and date. The samples were transported to the field office for storage and then to Ertec Western's Long Beach office in pickup trucks.

A5.3.4 Logging

The procedures for field visual classification of soil and rock encountered from the trenches, test pits, and surficial samples were basically the same as the procedures for logging of borings (Section A5.1.3). For excavations shallower than 4 feet (1.2 m), technicians entered the excavations and logged them. Logging of the excavations deeper than 4 feet (1.2 m) was accomplished from the surface and by observing the backhoe bucket contents. Some trench walls were photographed prior to backfilling.

Each field trench, test pit, and surficial sample log included trench, test pit, or surficial sample number; project name, number and location; name of excavator; type of excavation equipment; name of logger; and date logged. As excavations proceeded, the soil types encountered were visually classified and described as outlined in Section A5.5, "Field Visual Soil Classification." Section A5.5 also discusses other pertinent data and observations made which were entered on the logs during excavation.

A5.4 CONE PENETROMETER TESTS

A5.4.1 Equipment

The equipment consisted of a truck-mounted (17.5 tons [15,877 kg] gross weight) electronic cone penetrometer equipped with a 15-ton (13,608 kg) friction cone (cone end resistance capacity of 15 tons [13,608 kg] and 4-1/2-ton [4082 kg] limit on the friction sleeve). All operating controls, recorder, cables, and ancillary equipment were housed in the specially designed vehicle which was completely self-contained. The penetrometer, the key element of the system, contained the necessary load cells and cable connections. One end of the unit was threaded to receive the first sounding rod. When carrying out the tests, hollow rods with an outside diameter of 1.42 inches (3.6 cm) and a length of 3.3 feet (1.0 m) were used to push down the cone.

The hydraulic thrust system was mounted over the center of gravity of the truck, permitting use of the full 17.5-ton truck weight as load reaction.

The cone had an apex angle of 60° and a base area of 2.3 in^2 (15 cm^2). The resistance to penetration was measured by a built-in load cell in the tip and was relayed to the surface recorder via cables in the sounding rods. The friction sleeve, having an area of 31.8 in^2 (205 cm^2), was fitted above the cone base. The local friction was measured by load cells mounted in the friction sleeve and recorded in the same manner as the end resistance. The end resistance and friction resistance were recorded on a strip chart.

A5.4.2 Test Method

Tests were performed in accordance with ASTM D 3441-75T, "Tentative Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil." Basically, the test was conducted by positioning the electronic cone penetrometer truck over the designated area for testing, setting the outriggers on the ground surface, checking the level of the rig, then pushing the cone into the ground at a rate of 0.79 in/sec (2 cm/sec) until refusal (defined as the capacity of the cone, friction sleeve, or hydraulics system) or the desired depth of penetration was reached.

A5.5 FIELD VISUAL SOIL CLASSIFICATION

A5.5.1 General

All field logging of soils was performed in accordance with the procedures outlined in this section. Soil samples were visually classified in the field in general accordance with the procedures of ASTM D 2488-69, Description of Soils (Visual-Manual Procedure). The ASTM procedure is based on the Unified Soil Classification System (see Table A5-1). It describes several visual and/or manual methods which can be used in the field to estimate the USCS soil group for each sample. The following section details several of the guidelines used in the field for describing soils, drilling and excavating conditions, and unusual conditions encountered.

A5.5.2 Soil Description

Soil descriptions entered on the logs of borings, trenches, test pits, and surficial samples generally included those listed as follows.

Coarse-Grained Soils	Fine-Grained Soils
USCS Name and Symbol	USCS Name and Symbol
Color	Color

Coarse-Grained Soils	Fine-Grained Soils
Range in Particle Size	Consistency
Gradation (well, poorly)	Moisture Content
Density	Plasticity
Moisture Content	Reaction to HCl
Particle Shape	
Reaction to HCl	

Some additional descriptions or information recorded for both coarse- and fine-grained soils included: degree of cementation, secondary material, cobbles and boulders, and depth of change in soil type.

Definitions of some of the terms and criteria used to describe soils and conditions encountered during the investigations follow.

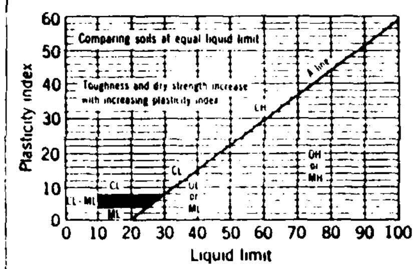
a. USCS Name and Symbol: Derived from Table A5-1, the Unified Soil Classification System. The soils were first designated as coarse- or fine-grained.

Coarse-grained soils are those in which more than half (by weight) of the particles are visible to the naked eye. In making this estimate, particles coarser than 3 inches (76 mm) in diameter were excluded. Fine-grained soils are those in which

Major divisions			Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights)	Group Symbols [a]	Typical Names	Information Required for Describing Soils	Laboratory Classification Criteria
Coarse-grained soils: More than half of material is *larger* than No. 200 sieve size[b] (The No. 200 sieve size is about the smallest particle visible to naked eye)	Gravels: More than half of coarse fraction is larger than No. 4 sieve size (For visual classification, the ¼ in. size may be used as equivalent to the No. 4 sieve size)	Clean gravels (little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	*GW*	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name; indicate approximate percentages of sand and gravel, maximum size; angularity, surface condition, and hardness of the coarse grains; *local or geologic name* and other pertinent descriptive information; and symbols in parentheses	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*GP*	Poorly graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for *GW*
		Gravels with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures see *ML* below)	*GM*	Silty gravels, poorly graded gravel-sand-silt mixtures	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics	Atterberg limits below "A" *line*, or *PI* less than 4 — Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*GC*	Clayey gravels, poorly graded gravel-sand-clay mixtures		Atterberg limits above "A" line, with *PI* greater than 7
	Sands: More than half of coarse fraction is smaller than No. 4 sieve size	Clean sands (little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	*SW*	Well graded sands, gravelly sands, little or no fines	Example: *Silty sand*, gravelly; about 20% *hard, angular gravel particles* ½-in. maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength; well compacted and moist in place; alluvial sand; (*SM*)	$C_U = \frac{D_{60}}{D_{10}}$ Greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			Predominantly one size or a range of sizes with some intermediate sizes missing	*SP*	Poorly graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for *SW*
		Sands with fines (appreciable amount of fines)	Nonplastic fines (for identification procedures, see *ML* below)	*SM*	Silty sands, poorly graded sand-silt mixtures		Atterberg limits below "A" line or *PI* less than 5 — Above "A" line with *PI* between 4 and 7 are *borderline* cases requiring use of dual symbols
			Plastic fines (for identification procedures, see *CL* below)	*SC*	Clayey sands, poorly graded sand-clay mixtures		Atterberg limits below "A" line with *PI* greater than 7

Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5% *GW, GP, SW, SP*; More than 12% *GM, GC, SM, SC*; 5% to 12% *Borderline* cases requiring use of dual symbols

Major divisions		Identification Procedures on Fraction Smaller than No. 40 Sieve Size: Dry Strength (crushing characteristics)	Dilatancy (reaction to shaking)	Toughness (consistency near plastic limit)	Group Symbols	Typical Names	Information Required for Describing Soils
Fine-grained soils: More than half of material is *smaller* than No. 200 sieve size	Silts and clays liquid limit less than 50	None to slight	Quick to slow	None	*ML*	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains; colour in wet condition, odour if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses
		Medium to high	None to very slow	Medium	*CL*	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
		Slight to medium	Slow	Slight	*OL*	Organic silts and organic silt-clays of low plasticity	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remoulded states, moisture and drainage conditions
	Silts and clays liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	*MH*	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	
		High to very high	None	High	*CH*	Inorganic clays of high plasticity, fat clays	Example: *Clayey silt*, brown; slightly plastic; small percentage of fine sand; *numerous vertical root holes*; firm and dry in place; loess; (*ML*)
		Medium to high	None to very slow	Slight to medium	*OH*	Organic clays of medium to high plasticity	
Highly Organic Soils		Readily identified by colour, odour, spongy feel and frequently by fibrous texture			*Pt*	Peat and other highly organic soils	



Plasticity chart
for laboratory classification of fine grained soils

From Wagner, 1957.

[a] *Boundary classifications*. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example *GW-GC*, well graded gravel-sand mixture with clay binder.

[b] All sieve sizes on this chart are U.S. standard.

Field Identification Procedure for Fine Grained Soils or Fractions

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dilatancy (Reaction to shaking)

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough *water if necessary to make* the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a *plastic clay* has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Dry Strength (Crushing characteristics):

After removing particles larger than No. 40 sieve size, mould a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the *CH* group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

Toughness (Consistency near plastic limit):

After removing particles larger than the No. 40 sieve size, a specimen of soil about one-half inch cube in size, is moulded to the consistency of putty. If too dry, water must be added and if sticky, the specimen *should be spread out in a thin layer* and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eight inch in diameter. The thread is then folded and re-rolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

After the thread crumbles, the pieces should be *lumped together* and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, *the more potent* is the colloidal clay fraction in the soil. Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line.

Highly organic clays have a very weak and spongy feel at the plastic limit.

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UNIFIED SOIL CLASSIFICATION SYSTEM

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TABLE A5-1

more than half (by weight) of the particles are so fine that they cannot be seen by the naked eye. The distinction between coarse- and fine-grained can also be made by sieve analysis with the No. 200 sieve (.074 mm) size particle considered to be the smallest size visible to the naked eye. In some instances, the field technicians describing the soils used a number 200 sieve to estimate the amount of fine-grained particles. The coarse-grained soils are further divided into sands and gravels by estimating the percentage of the coarse fraction larger than the No. 4 sieve (about 1/4 inch or 5 mm). Each coarse-grained soil is then qualified as silty, clayey, poorly graded, or well-graded as discussed under plasticity and gradation.

Fine-grained soils were identified in the field as clays or silts with appropriate adjectives (clayey silt, silty clay, etc.) based on the results of dry strength, dilatancy, and plastic thread tests (see ASTM D 2488-69 for details of these tests).

Dual USCS symbols and adjectives were used to describe soils exhibiting characteristics of more than one USCS group.

b. Color: Color descriptions were recorded using the following terms with abbreviations in parentheses.

White (w)	Green (gn)
Yellow (y)	Blue (bl)
Orange (o)	Gray (gr)
Red (r)	Black (blk)
Brown (br)	

Color combinations as well as modifiers such as light (lt) and dark (dk) were used.

c. Range in Particle Size: For coarse-grained soils (sands and gravels), the size range of the particles visible to the naked eye was estimated as fine, medium, coarse, or a combined range (fine to medium).

d. Gradation: Well-graded indicates a coarse-grained soil which has a wide range in grain size and substantial amounts of most intermediate particle sizes. A coarse-grained soil was identified as poorly graded if it consisted predominantly of one size (uniformly graded) or had a wide range of sizes with some intermediate sizes obviously missing (gap-graded).

e. Density or Consistency: The density or consistency of the in-place soil was estimated based on the number of blows required to advance the Fugro drive or split-spoon sampler, the drilling rate (difficulty) and/or hydraulic pulldown needed to drill, visual observations of the soil in the trench or test pit walls, ease (or difficulty) of excavation of trench or test

pit, or trench or test pit wall stability. For fine-grained soils, the field guides to shear strength presented below were also used to estimate consistency.

- Coarse-grained soils - GW, GP, GM, GC, SW, SP, SM, SC (gravels and sands)

Consistency	N-Value (ASTM D 1586-67), Blows/Foot
Very Loose	0 - 4
Loose	4 - 10
Medium Dense	10 - 30
Dense	30 - 50
Very Dense	>50

- Fine-grained Soils - ML, MH, CL, CH (Silts and Clays)

Consistency	Shear Strength (ksf)	(KN/m^2)	Field Guide
Very Soft	<0.25	<12.0	Sample with height equal to twice the diameter, sags under own weight
Soft	0.25-0.50	12.0-23.9	Can be squeezed between thumb and forefinger
Firm	0.50-1.00	23.0-42.9	Can be molded easily with fingers
Stiff	1.00-2.00	47.9-95.8	Can be imprinted with slight pressure from fingers
Very Stiff	2.00-4.00	9.58-191.5	Can be imprinted with considerable pressure from fingers
Hard	>4.00	>191.5	Cannot be imprinted by fingers

f. Moisture Content: The following guidelines were used in the field for describing the moisture in the soil samples:

Dry	: No feel of moisture - dry like powder
Slightly Moist	: Much less than optimum moisture
Moist	: Near optimum moisture for soil - provides apparent choesion
Very Moist	: Much greater than optimum moisture
Wet	: At or near saturation

g. Particle Shape: Coarse-grained soils

Angular : Particles have sharp edges and relatively plane sides with unpolished surfaces

Subangular: Particles are similar to angular but have somewhat rounded edges

Subrounded: Particles exhibit nearly plane sides but have well-rounded corners and edges

Rounded : Particles have smoothly curved sides and no edges

h. Reaction to HCl: As an aid for identifying cementation, some soil samples were tested in the field for their reaction to dilute hydrochloric acid. The intensity of the HCl reaction was described as none, weak, or strong.

i. Degree of Cementation: Based on the intensity of the HCl reaction and observation, the degree of cementation of a soil layer was described as weak to strong. Also, the following stages of development of caliche (cemented) profile were indicated where applicable.

Stage	Gravelly Soils	Nongravelly Soils
I	Thin, discontinuous pebble coatings	Few filaments or faint coatings
II	Continuous pebble coatings, some interpebble fillings	Few to abundant nodules, flakes, filaments
III	Many interpebble fillings	Many nodules and internodular fillings
IV	Laminar horizon overlying plugged horizon	Increasing carbonate impregnation

j. Secondary Material: Example - Sand with trace to some silt

Trace	5-12%	(by dry weight)
Little	13-20%	(by dry weight)
Some	>20%	(by dry weight)

k. Cobbles and Boulders: A cobble is a rock fragment, usually rounded or subrounded, with an average diameter between 3 and 12 inches (76 and 305 mm). A boulder is a rock fragment, usually rounded by weathering or abrasion, with an average diameter of 12 inches (305 mm) or more. The presence of cobbles and/or boulders was identified by noting the sudden change in drilling difficulty or cuttings in borings or by visual observation in excavations. An estimate of the size, range, and percentage of cobbles and/or boulders in the strata was recorded on the logs.

l. Depth of Change in Soil Type: During drilling of borings, the depth of changes in soil type was determined by observing samples, drilling rates, changes in color or consistency of drilling fluid, and relating these to depth marks on the drilling rods. In excavations, strata thicknesses were measured with

a tape. All soil type interfaces were recorded on the logs by a horizontal line at the approximate depth mark.

In addition to the observations recorded relating to soil descriptions, remarks concerning drilling difficulty, loss of drilling fluid in the boring, water levels encountered, trench wall stability, ease of excavation, and other unusual conditions were recorded on the logs.

A5.6 LABORATORY TESTS

Laboratory tests were performed on selected representative undisturbed and bulk samples. All laboratory tests (except chemical tests) were performed in Ertec Western's Long Beach laboratory. The chemical tests were conducted by Pomeroy, Johnson, and Bailey Laboratories of Pasadena, California. All tests were performed in general accordance with the American Society for Testing and Materials (ASTM) procedures. The types of tests performed and their ASTM designations are summarized as follows.

Type of Test	ASTM Designation
Unit Weight	D 2937-71
Moisture Content	D 2216-71
Particle-Size Analysis	D 422-63
Liquid Limit	D 423-66
Plastic Limit	D 424-59
Triaxial Compression	D 2850-70
Unconfined Compression	D 2166-66
Direct Shear	D 3080-72
Consolidation	D 2435-70
Compaction	D 1557-70
California Bearing Ratio (CBR)	D 1883-73
Specific Gravity	D 854-58
Water Soluble Sodium	D 1428-64
Water Soluble Chloride	D 512-67
Water Soluble Sulfate	D 516-68
Water Soluble Calcium	D 511-72
Calcium Carbonate	D 1126-67
Test for Alkalinity (pH)	D 1067-70

A5.7 DATA ANALYSIS AND INTERPRETATION

A5.7.1 Preparation of Final Logs and Laboratory and Field Test Summary Sheets

The field logs of all borings, trenches, test pits, and surficial sample excavations were prepared by systematically combining the information given on the field logs with the laboratory test results. The resultant logs include generally the following information: description of soil types encountered; sample

types of intervals, lithology (graphic soil column); estimates of soil density or consistency; depth locations of changes in soil types; remarks concerning trench wall stability; drilling difficulty, cementation, and cobbles and boulders encountered; and the total depth of exploration. Laboratory test results presented in the logs include dry density and moisture content; percent of gravel, sand, and fines; and liquid limit and plasticity index. Also, miscellaneous information such as surface elevation, surficial geologic unit, date of activity, equipment used, and dimensions of the activity is included on the log.

Laboratory data were summarized in tables. All samples which were tested in the laboratory were listed. Results of sieve analyses, hydrometer, Atterberg limits, in-situ dry strength and moisture content tests, and calculated degree of saturation and void ratio were entered on the tables. Test summary sheets for triaxial compression, unconfined compression, direct shear, consolidation, chemical, CBR, and compaction tests were prepared separately.

The Cone Penetrometer Test results consist of continuous plots of cone resistance, friction sleeve resistance, and friction ratio versus depth from ground surface. Beside the plot is shown a soil column with USCS soil types encountered at the test location.

Volume II titled "Geotechnical Data" presents the following finalized basic engineering data.

Boring Logs	Section II - 6.0
Trench and Test Pit Logs	Section II - 7.0
Surficial Sample Logs	Section II - 8.0
Laboratory Test Results	Section II - 9.0
Cone Penetrometer Test Results	Section II - 10.0

A5.7.2 Soil Characteristics

A5.7.2.1 General

The soil characteristics are discussed in two parts, surface soils and subsurface soils. The following three tables were prepared and are presented in Sections 3.3 and 3.4 of the report.

1. Characteristics of Surficial Soils;
2. Thickness of Low-Strength Surficial Soils; and
3. Characteristics of Subsurface Soils.

The following sections, A5.7.2.2 and A5.7.2.3, explain the data analyses and interpretation used in preparing the above tables.

A5.7.2.2 Surface Soils

In order to define the characteristics of the surficial soils, data from trenches, test pits, borings, surficial soil samples,

cone penetrometer tests, and surficial geologic maps were reviewed in conjunction with the laboratory test results. The soils were then grouped into three categories of soils with similar general characteristics. These categories, their descriptions, and associated characteristics were tabulated. This table (Characteristics of Surficial Soils, Table 3-1) includes soil descriptions by the Unified Soil Classification System, predominant surficial geologic units, the estimated areal extent (percent) of each category, important physical properties summarized from laboratory test results, and certain road design related data.

The important physical properties summarized include the estimated cobbles content, grain-size analyses, and Atterberg limits. Ranges for these properties were determined from the field logs and laboratory test results. These ranges are useful for categorizing soils, evaluating construction techniques, and providing data for preliminary engineering evaluations and for use by other MX participants.

Road design data presented in Table 3-1 were developed from field and laboratory tests and consist of three distinct groups:

1. Laboratory test results;
2. Suitability of soils for road use; and
3. Low-strength surficial soil.

These road design related data were considered important because roads (interconnecting and secondary) constitute a major portion of the geotechically related costs for the vertical and horizontal shelter basing mode. The following paragraphs briefly discuss the development of road design data.

a. Laboratory Test Results: These include ranges of maximum dry density, optimum moisture content (ASTM D 1557-70) and CBR (ASTM D 1883-73) at 90 percent relative compaction for each soil category. The maximum dry density and optimum moisture content are important quality control parameters during roadway construction. California Bearing Ratio is the ratio of the resistance to penetration developed by a subgrade soil to that developed by a specimen of standard crushed-rock base material and is the basis for many empirical road design methods used in this country.

b. Suitability of Soils for Road Use: Included in this group is suitability of soils for use as road subgrade, subbase, or base. Parameters used to make these qualitative assessments were characteristics related to CBR, frost susceptibility, drainage, and volume change potential. The following guidelines were used in estimating the suitability of soils for road use.

1. Suitability as a road subgrade.

Very Good - soils which can be compacted with little effort to high CBR values (CBR >30), exhibit low frost

susceptibility, fair to good drainage, and low volume change potential.

Good - soils which can be compacted with some effort to moderate CBR values (CBR 15-30), exhibit moderate frost susceptibility, fair drainage, and medium volume change potential.

Fair - soils which can be compacted with considerable effort to moderate CBR values (CBR 15-30), exhibit moderate to high frost susceptibility, fair to poor drainage, and medium volume change potential.

Poor - soils which require considerable effort for compaction to even low CBR values (CBR <15), exhibit high frost susceptibility, poor drainage, or high volume change potential. These soils should generally be removed and replaced with better quality material.

2. Suitability as road subbase or base.

Good - soils which exhibit negligible frost susceptibility, good drainage, and negligible volume change potential.

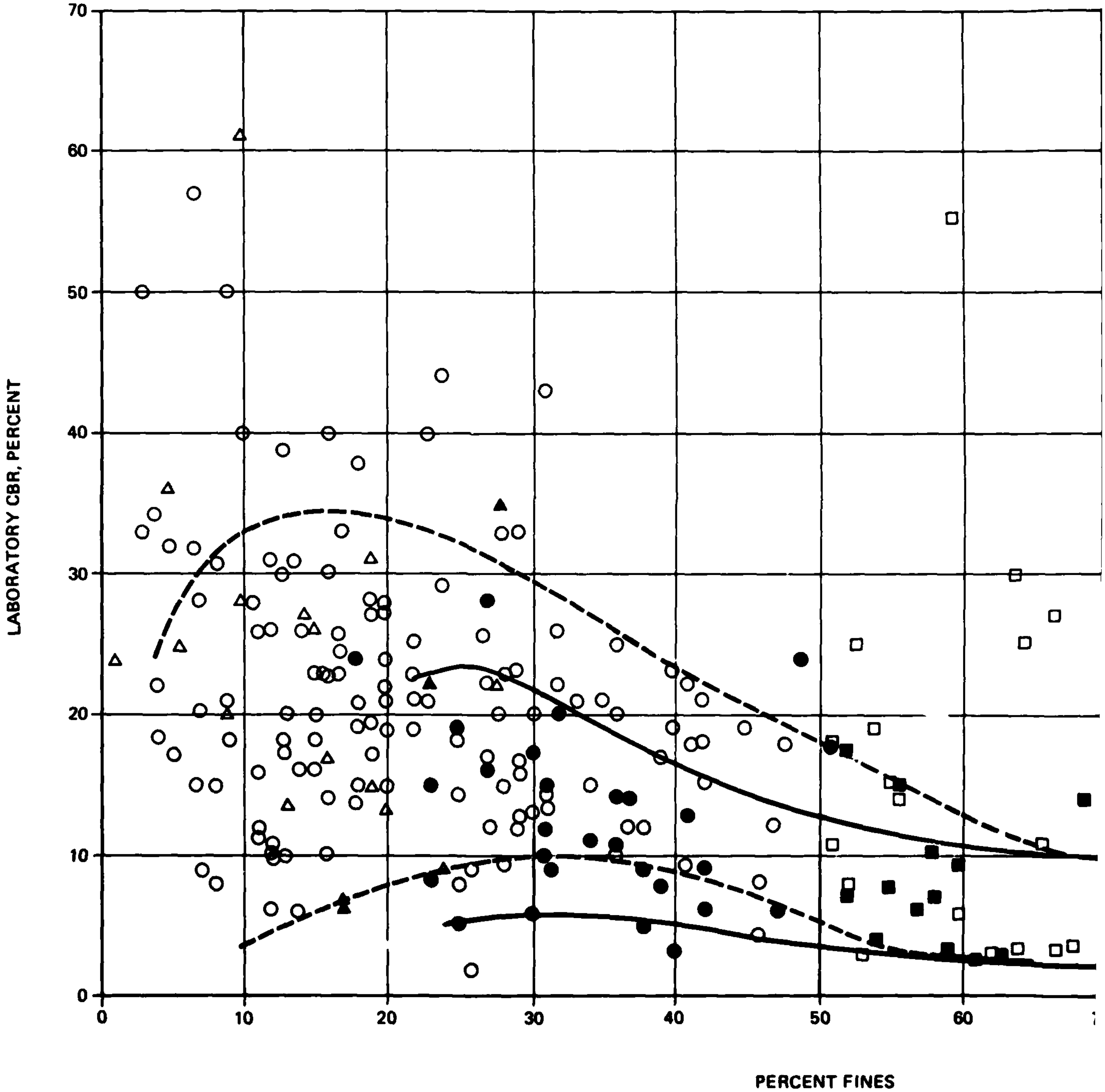
Fair - soils which require some treatment or processing to upgrade for use.

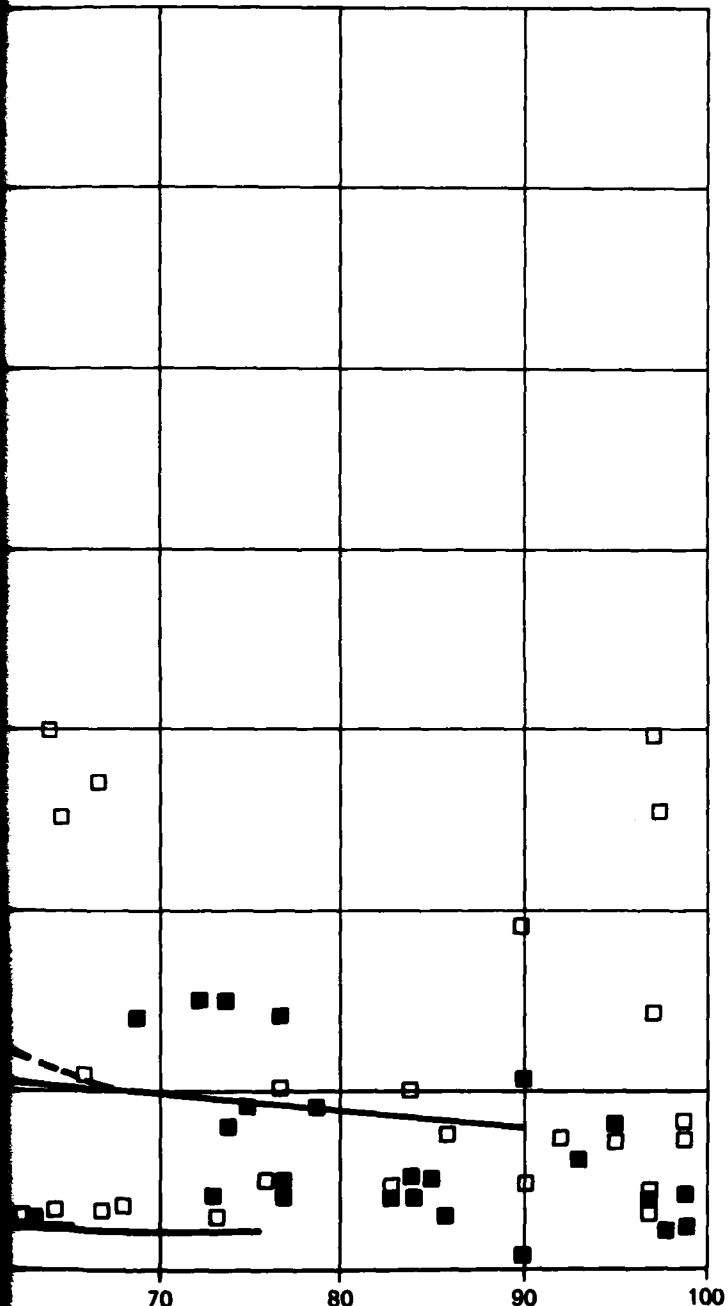
Poor - soils which would require relatively extensive processing or soil stabilization to upgrade for use.

Not Suitable - soils which cannot be modified to give adequate roadway support.

The parameters used in the aforementioned suitability ratings are discussed in the following paragraphs.

i. CBR Characteristics: California Bearing Ratio, which is commonly used for road design, is dependent on soil type. During Verification studies, a limited number of CBR tests were performed on several soil types which were representative of the surficial soils in the various Verification sites. Based on these test results, a relationship between CBR and percent fines (percent passing through No. 200 sieve) was established and is shown in Figure A5-1. Envelopes for clays and granular soils with plastic fines and silts and granular soils with nonplastic fines are shown in the figure. This plot was used to estimate the range of laboratory CBR values for the various surficial soil categories.


LABORATORY CBR, PERCENT
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
PERCENT FINES



EXPLANATION

- △ Gravels with nonplastic fines (GM, GW, GP, GP-GM, GW-GM)
- ▲ Gravels with plastic fines (GC, GC-GM)
- ○ Sands with nonplastic fines (SP, SW, SM, SP-SM, SW-SM)
- ● Sands with plastic fines (SC, SC-SM)
- □ Silts (ML)
- ■ Clays (CL, CH, CL-ML)
- - - - - - Envelope for silts and granular soils with nonplastic fines
- ——— Envelope for clays and granular soils with plastic fines

NOTES:

1. Fines correspond to soil passing through No 200 (0.074mm opening) sieve.
2. California Bearing Ratio at 90% relative compaction.
3. Soil types (GM, SC) are based on Unified Soil Classification System.

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PLOT OF LABORATORY CBR VERSUS PERCENT FINES VERIFICATION SITES, NEVADA-UTAH

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ii. Other Characteristics: These characteristics pertain to frost susceptibility, drainage, and volume change potential. They were estimated based on the physical properties of the soils, results of consolidation tests (for volume change potential), published literature, and our experience. Following are the definitions of these characteristics.

1. Frost susceptibility is defined as potential for detrimental ice segregation upon freezing or loss of strength upon thawing.

Low	- negligible to little potential
Moderate	- some potential
High	- considerable potential

2. Drainage characteristics pertain to internal movement of water through soil.

Good	- materials which drain rapidly and do not tend to plug with fines
Fair	- natural internal drainage is fairly rapid but there is some tendency for plugging of voids with fines
Poor	- internal drainage is somewhat slow and plugging with fines can often occur
Practically Impervious	- materials which exhibit almost no natural internal drainage

3. Volume change potential corresponds to soil swelling or shrinkage due to change in moisture content.

Low	- 0 to 2 percent volume change
Medium	- 2 to 4 percent volume change
High	- > 4 percent volume change

c. Low-Strength Surficial Soil: The roads for the MX system will be built on existing ground surface with minimum cut and fill. Therefore, the costs of roads depend on the consistency (or strength) of the surficial soil. In order to evaluate the strength of the surficial soils, cone penetrometer test results were used.

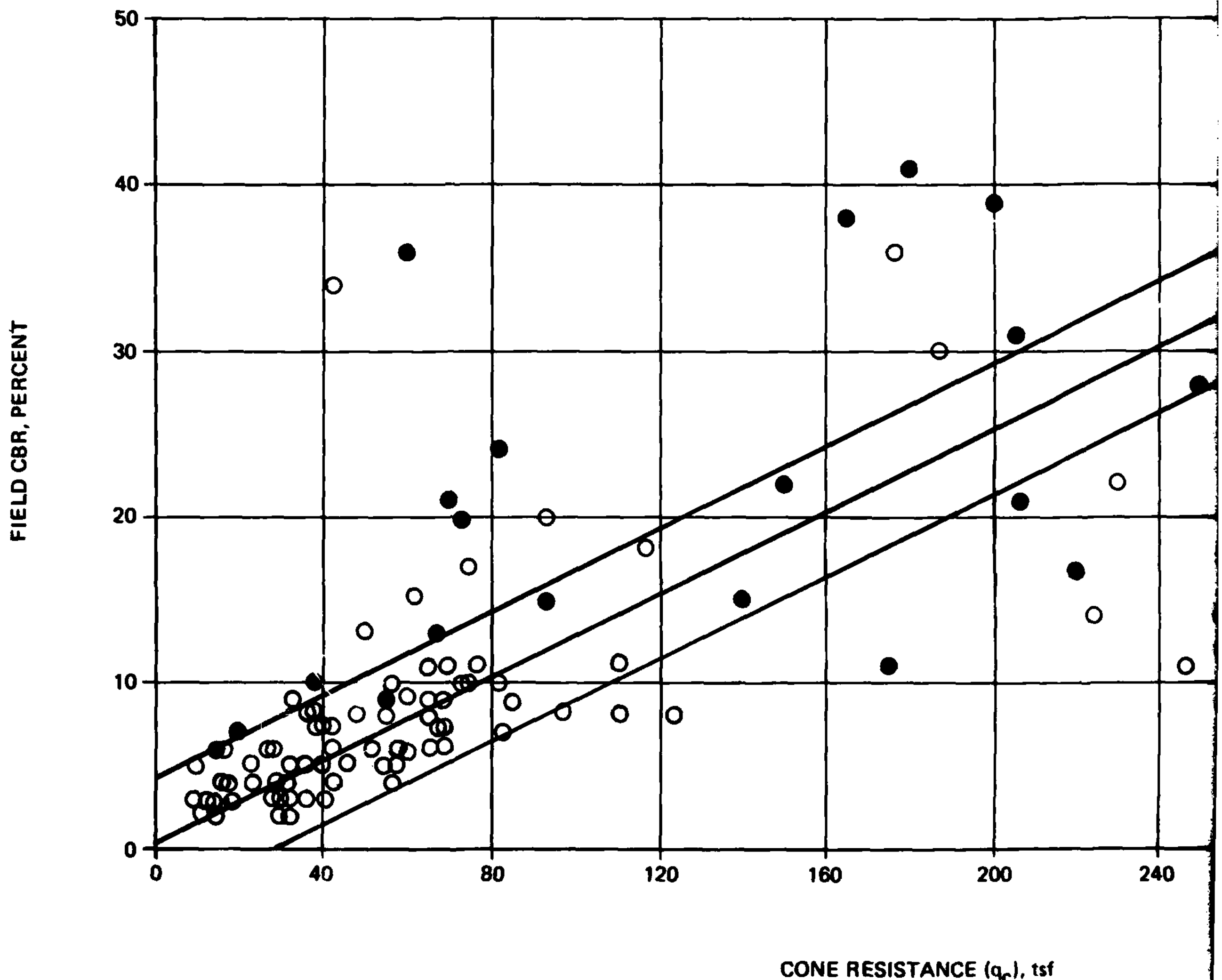
Low-strength surficial soil is defined as soil which will perform poorly (failure of subgrade) as a road subgrade at its present consistency when used directly beneath a road section. In order to define "low strength" using CPT results, the following four approaches were pursued. These approaches are subjective and qualitative and are based on our experience as well as published literature.

i. Field visual observations: During logging of the borings, the excavation of trenches, test pits, and obtaining surficial soil samples, consistency or compactness of the surficial soils was described qualitatively. A detailed comparison of the CPT results (cone end resistance) and the consistency of the soils was done for different soil types. Using engineering judgment, an upper limit cone resistance was established which encompassed a majority of the soils likely to perform poorly as road subgrades.

ii. Standard Penetration Test (SPT): SPT is very widely used and accepted in geotechnical engineering practice in this country. A study of available literature revealed that the ratio of cone resistance (q_c, tsf) to standard penetration resistance (N, blows per foot) has a certain range for different soil types. In Verification studies, limited field SPTs were performed in some valleys. Ratios of q_c/N were computed for these tests and were found to be comparable to those reported in literature for similar soil types. Using the relationships applicable to the soils present in the Verification sites, an upper limit of cone resistance, equivalent to midrange of "medium dense" category, (SPT = 10 to 30 blows per foot) was established for defining the "low-strength" surficial soils.

iii. In-Situ Dry Density: A comparison was made between in-situ dry densities determined from Fugro Drive and Pitcher samples obtained from soil borings and CPT results at the same locations and depths. From this comparison, it was observed that identifiable trends do exist between cone resistance values and soil densities. In this case, an upper limit of cone resistance, equivalent to midrange of "medium dense" category (relative compaction), was established for defining the "low-strength" surficial soils.

iv. Field CBR Tests: During Verification studies, field CBR tests were performed in Reveille, Railroad, Pine, Wah Wah, Steptoe, Lake, Spring, Stone Cabin, Hot Creek, and Big Smoky valleys. The procedures for conducting the CBR tests were as described in the U.S. Army Corps of Engineers' Technical Manual (TM) 5-30, pp. 2-86 to 2-96. The test results were compared to Cone Penetrometer Tests performed at the same location. A plot of average field CBR and average cone resistance was prepared and is presented in Figure A5-2. The plot shows the results of the tests in sands only, since tests in gravel and fine-grained soils were very few. Although there is considerable scatter, majority of the data points fall in a band which is shown in Figure A5-2. From this plot, a range of CPT resistance corresponding to low field CBR values (indicating low-strength surficial soils) was established.

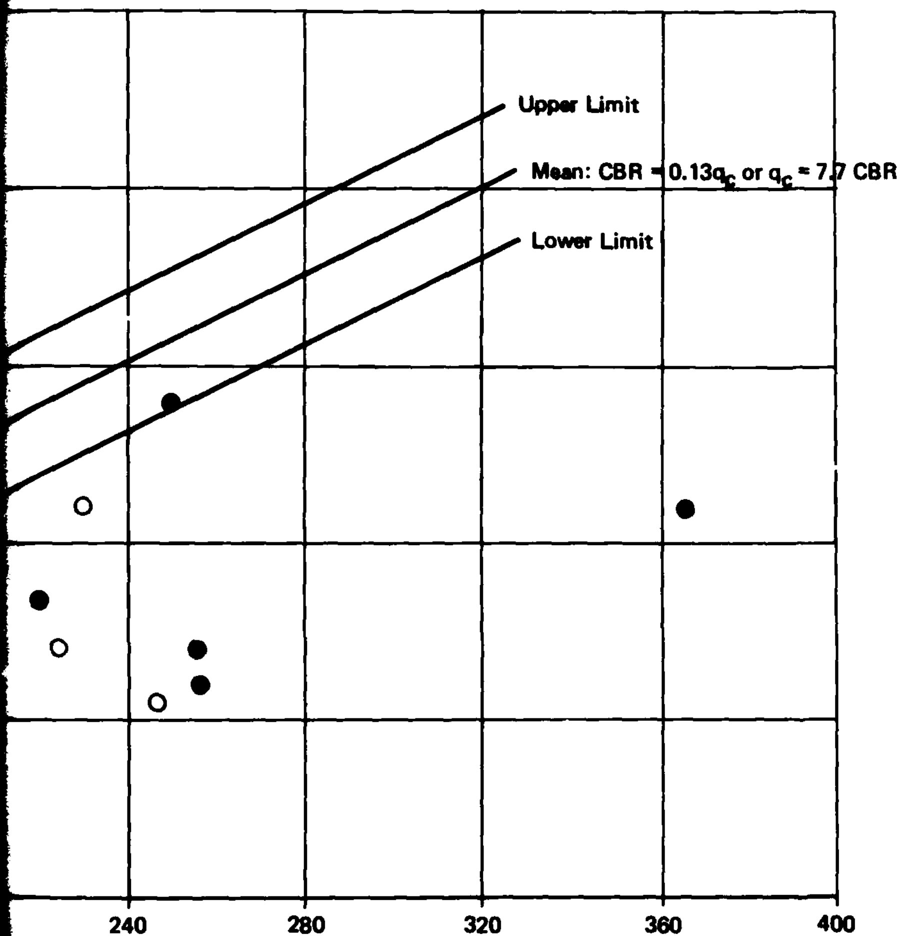


NOTES: 1. Data are for coarse-grained soils tested in Big Smoky, Reveille, Railroad, Pine, Wah Wah, Spring, Lake, Stone Cabin, Reveille and Hot Creek Verification Sites.

2. Band between the upper and lower limits includes 74% of all the data points, and includes 85% non-caliche data points

3. Solid points indicates caliche data points.

4. Depth of CBR is from zero to four feet.



ah, Spring, Lake,

ludes 85% non-

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RELATIONSHIP BETWEEN FIELD CBR AND CPT CONE RESISTANCE VERIFICATION VALLEYS, NEVADA-UTAH

30 JUN 81 FIGURE A5-2

As a result of the preceding four approaches, the following criteria for defining low-strength surficial soil were established:

q_c <120 tsf (117 kg/cm^2) for coarse-grained soils
q_c < 80 tsf (78 kg/cm^2) for fine-grained soils

These criteria are preliminary at this stage and may be revised as more data become available from future Verification studies. The criteria were used to determine the extent of low-strength surficial soil at each CPT location. The results are tabulated in Table 3-2, "Thickness of Low-Strength Surficial Soil."

A5.7.2.3 Subsurface Soils

Characteristics of the subsurface soils were developed using data from seismic refraction surveys, borings, trenches, test pits, and laboratory tests.

The soils were divided into coarse-grained and fine-grained soils in two ranges of depth, 0 to 20 feet and 20 to 160 feet (0 to 6 m and 6 to 49 m). Physical and engineering properties of the soils were then tabulated as "Characteristics of Subsurface Soils" (Table 3-4) based on laboratory test results on representative samples. The table includes soil descriptions, Unified Soil Classification System symbols, the estimated subsurface extent of each soil group, comments on the degree of cementation, estimated cobbles content, and ranges of values from the following laboratory tests: dry density, moisture content, grain-size distribution, liquid limit, plasticity index, unconfined compression, triaxial compression, and direct shear.

The excavatability and stability of excavation walls of a horizontal or a vertical shelter were evaluated from the subsurface data using seismic velocities, soil types, shear strength, presence of cobbles and boulders, and cementation. Problems encountered during trench and test pit excavations and drilling of borings were also considered in the evaluation.

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